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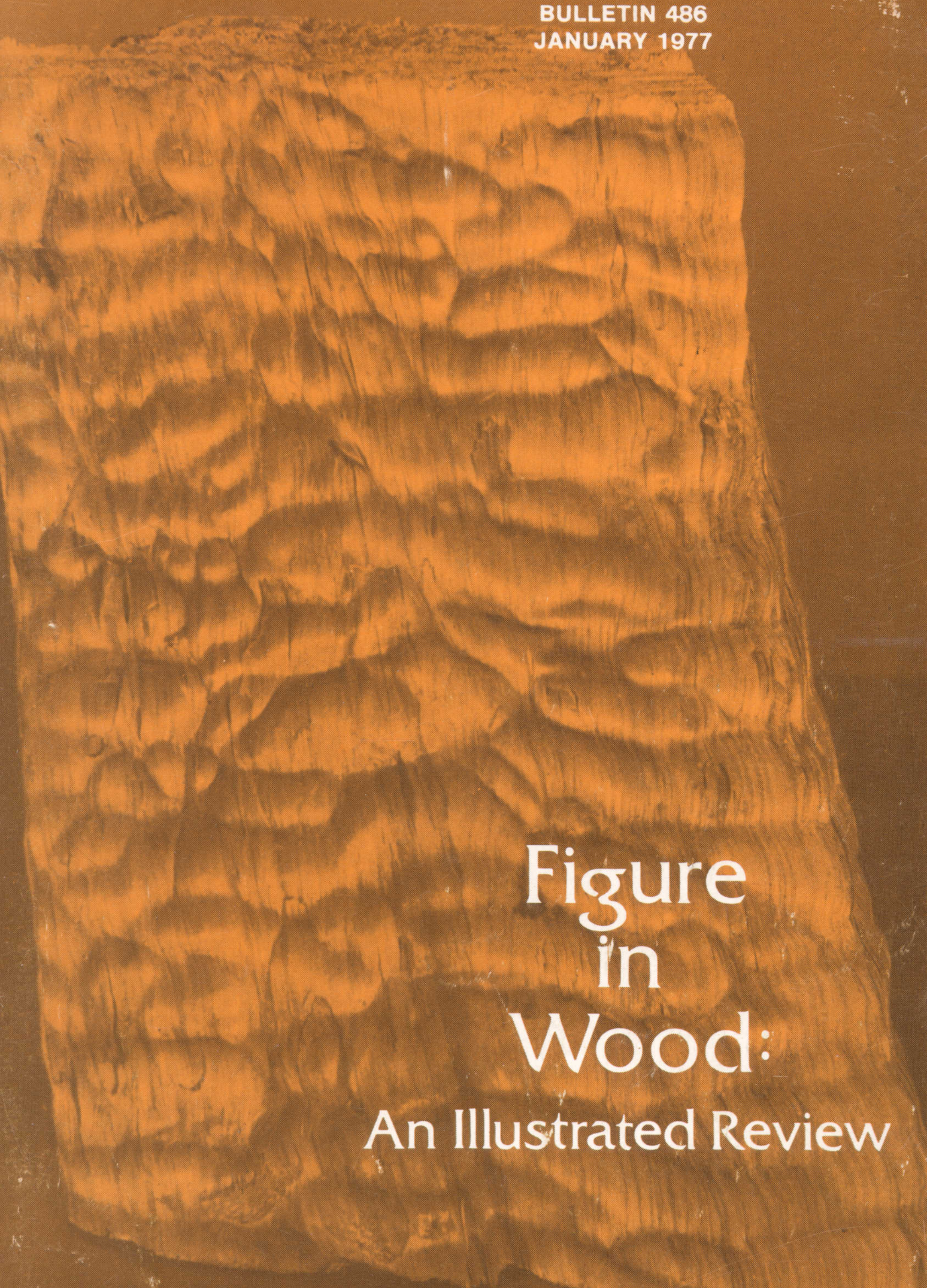

Figure in Wood: An Illustrated Review

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CONTENTS

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FIGURE IN WOOD: An Illustrated Review[1]

by:
HAROLD O. BEALS and TERRY C. DAVIS[2]

INTRODUCTION

Color, luster, texture, grain, and figure are the major gross characteristics that aid in wood identification and provide a basis for decorative qualities. High values of most prized woods may be traced to unusual or rare features that involve one or more of these characteristics. Figured wood has been esteemed for its beauty and universal appeal for centuries. Certain types of figured wood are primary materials for numerous small but important industries throughout the world. Although comparatively little is known concerning figured wood, the subject has received more attention in recent years. Available literature is scattered widely in many journals, both foreign and domestic, and contradictory statements abound. An annotated bibliography of figure in wood that included abstracts of articles not found in other bibliographies was published in 1973 (9).

Probably figure is the most desirable, the least understood, and certainly the most complex gross characteristic of wood. Any design, pattern, or distinctive marking that appears either consistently or intermittenly on longitudinal surfaces of wood may be described as figure. A restricted definition would include only decorative qualities desired for furniture, paneling, gunstocks, or musical instruments.

Figure in wood results from combinations of color, luster, texture, and grain. Color and luster have ordinarily accepted meanings (63).

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Texture depends on size, distribution, and proportional volumes of cellular elements composing wood. Depending on relative sizes and distribution of cellular elements, texture may be fine or coarse, even or uneven. Individual elements in fine-textured wood are indistinguishable with aid of a hand lens; in coarse-textured woods, they are usually distinguishable with magnification. Grain of wood commonly is used with a variety of meanings, generally depending on the modifier and often (inaccurately) in place of texture (fine grain). Meaning of grain here is confined to direction of wood fibers relative to the longitudinal axis of the bole and to one another (straight grain).

Figure may be defined as the pattern produced on a wood surface by annual growth layers, rays, and knots; by irregular coloration; and by deviations from straight, regular grain. Three broad types of figure in wood are recognized.

(1) Normal figure, which results from textural variation, depends largely on the plane of cutting. Tangential cutting (plain sawing or rotary cutting) usually results in nested V's or U's when the wood has visible growth layers. Radial cuts (quarter sawn) reveal growth layers in relatively straight, vertical lines. All gradations between tangential and radial surfaces occur. Sections of rays exposed by quarter sawing are prominent in many species as ray-fleck. Knots may or may not be present. Decorative knotty paneling is mainly plain sawn to expose circular knots. Wood with no more than normal figure paradoxically is called unfigured in the lumber and veneer trade.

(2) Pigment figure, which results from infiltration of coloring materials in regular or irregular patterns, may be local or generalized and is influenced occasionally by the plane of cutting.

(3) Specific figure, which results from non-vertical alignment of longitudinal fibers, may be hidden or enhanced by cutting methods. Specific figure is the main subject of this treatise. Except where specified as general or pigment figure and in brief, labelled sections, the unmodified term means specific figure.

This publication contains a general presentation of figure in wood that includes many facets on the subject ranging from basic to highly specific. The objective is to present subject matter in a fashion to enhance knowledge and understanding of figure in wood. The first two broad types of figure as listed above are considered GENERAL figure and will be reviewed and illustrated only briefly. The last figure type is considered SPECIFIC figure and will be reviewed and illustrated in considerable detail.

FIGURE IN LIVING TREES

Most published work concerning figured trees has been based upon observations of logs or from lumber or veneer cut from such logs (2, 6, 23). Few studies have been made involving figure as it occurs in living trees.

Figure occurs in living trees primarily as variations or distortions in the vertical alignment of wood elements (grain) in either radial or tangential directions (or combinations of both) that result in common figure types known as stripe, blister, curl, wavy, and several variations that are described later in this report.

Detection of figure in living trees, either located in a stand or singly, is a difficult process and is considered by many to be an art developed only after many years of experience. There apparently is no reliable indicator of figure that can be used to recognize figured trees, individually or in stands.

Ecological factors, such as site, and morphological features of form, bark characteristics, foliage, or position in the stand often suggest the presence or absence of figure in trees; these indicators generally are used with caution even by experienced producers of figured wood. Intensive studies made in Europe on correlation of bark types with figured wood in birch have shown that certain bark characteristics are indicative of the presence but not necessarily any particular type or quality of figure (26, 27, 47, 54, 55, 56, 57, 58, 76, 78). Figured wood occasionally may be found in almost any tree species near roots or branches but is usually so limited in quantity and generally of such poor quality that it is considered a defect. In general, trees with figure concentrated in the butt or throughout lower portions appear no different from other trees in surrounding areas. Figured wood frequently may be present in poorly formed, damaged, or diseased trees but seldom in commercial quality. The figure known as "birdseye" for many years was thought to be associated with suppression or with some type of mechanical damage (1, 3, 34, 35, 66, 69). However, veneer manufacturers report that growth rate apparently has little effect on quantity or quality of the figure observed.

Although tree size sometimes is associated with figure, it is difficult to make valid size comparisions because of minimum size requirements for commercial veneer logs. However, commercially valuable figure is seldom found in trees less than 10 inches in diameter. Once initiated, figure becomes increasingly pronounced in subsequent growth rings. It usually diminishes with increasing stem height and almost always disappears above the first large limb. Figure frequently is concentrated in one or more stem quadrants; it is rare to find heavily figured wood throughout the entire bole circumference. Since blister and quilted figures in Oregon maple may develop at various heights in the bole, such trees may be overlooked for figured veneer logs when sampled only near the butt (10). These figures often occur in leaning trees. Although bark abnormalities are used by trained observers as indicators of figure, attempted use of bark characteristics to detect figured trees is most times unsuccessful (51).

Tropical woods often contain a stripe figure traceable to interlocked grain that sometimes is so common as to be considered a normal feature of certain species.

Techniques for detection of figured trees within forest stands usually consist of some type of axe-chip analysis to detect variations of fiber alignment on tangential surfaces (47, 67). This method has been used for centuries in search of "tone woods" for use in musical instrument manufacture. Axe-chip analysis normally is extended to include splitting small chip samples to determine straightness of grain in addition to figure depth and quality (Figure 1). Since wounding can induce stain, decay, insect damage, and other defects, these techniques should be used only on trees that will be harvested within a short time period.

GENERAL FIGURE IN WOOD

Figure is a term that describes certain well-defined patterns in wood from many tree species. Patterns that occur on wide surfaces of lumber or veneer are results of variations in texture, grain, and color, as well as methods of cutting.

Common methods of processing logs into lumber or veneer produce two pattern types based on the wide surface exposed, tangential or radial (Figure 2). These pattern types result from planes of section passing through the radially symmetrical woody cylinder at different positions. Tangential surfaces exposed in flat (or plain) sawing typically exhibit growth rings in a pattern of nested, V-shaped lines. Radial surfaces exposed in quarter-sawn (or edge-grain) lumber show growth rings as a series of parallel lines. True transverse (or cross) sections, which are perpendicular to the tangential and radial planes, rarely contribute to figure. Patterns exhibited by transverse surfaces are concentric circles or arcs.

Brochures from various trade organizations such as the Fine Hardwoods Association, Mahogany Association, American Walnut Manufacturing Association, and others contain general descriptions of various figure types with respect to portions of trees where different figures occur and the development of figure by different methods of veneer cutting. These discussions merely acquaint readers with various figure types and explain which figures are most common in particular species.

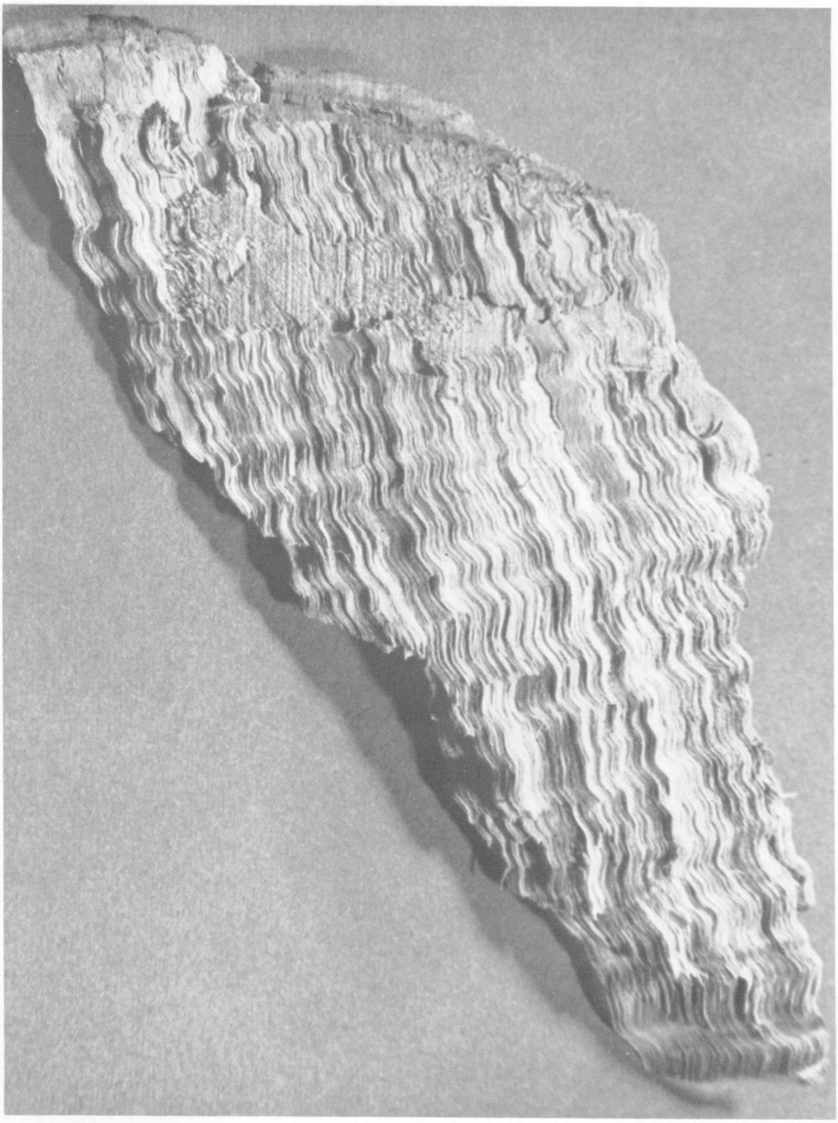


Figure 1. Axe-chip specimen of Oregon maple that shows a well-developed, high-quality fiddleback figure on the tangential surface. (Material supplied by N. H. Beer & Associates)

Publications of a more general or popular nature have appeared in recent years. Examples are papers describing burl formation in several

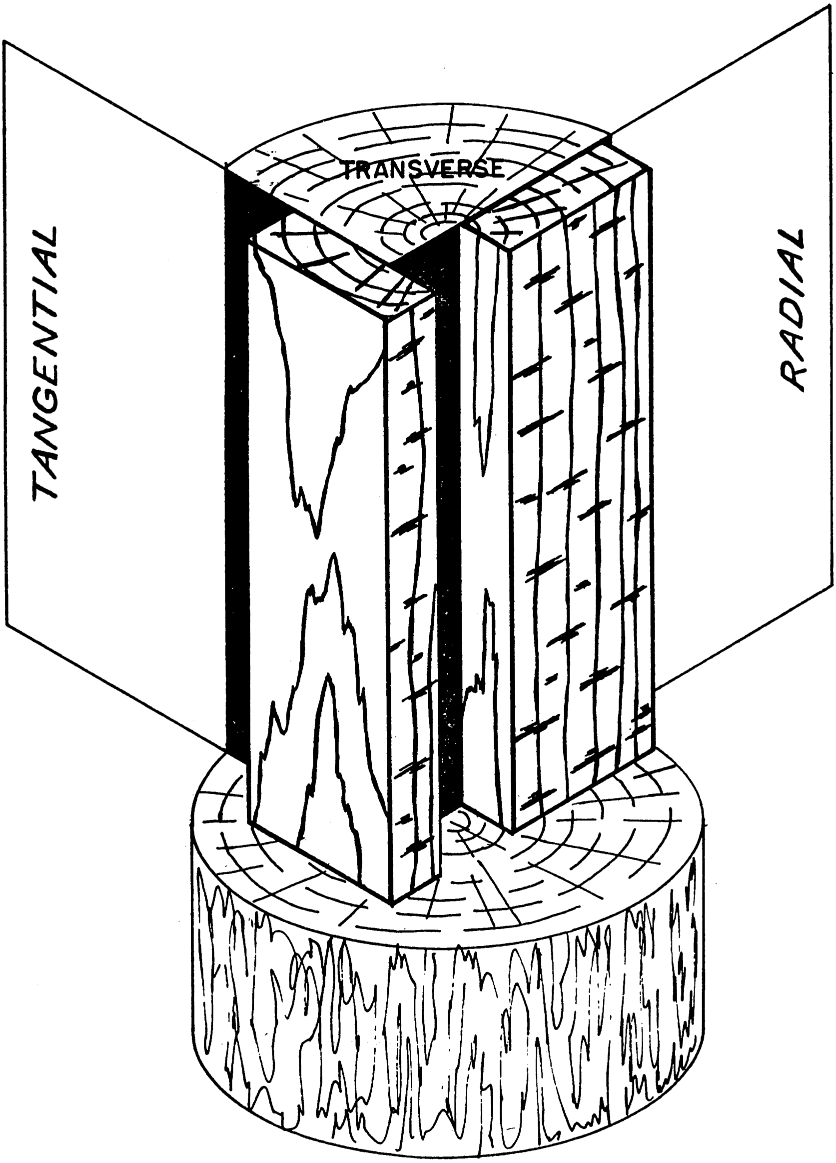


Figure 2. Diagrammatic log section that illustrates the relationship of tangential (t), radial (r), and transverse or cross (x) surfaces. Note patterns and growth-ring orientation on different surfaces.

species (53) and the curly (blister) figure occasionally found in southern pine (29). Others describe either figure in general and its use in furniture (64) or technical aspects of converting curly grained wood into veneer (22).

One of the best available general discussions concerning figure in wood is presented in the "Textbook of Wood Technology, Vol. I" (63); a more thorough treatment, however, occurred in an earlier edition that is out of print. Similar presentations concerning figured material may be found in trade circulars from Australia (2, 80).

Texture, Grain, and Figure

Texture is a term used to classify relative size of wood elements. Woods are considered fine-textured when individual elements are so small that they cannot be distinguished individually with a hand lens. Coarse textured woods have large individual elements that often can be observed without magnification. Texture often is confused with grain. Coarse-textured woods are described as "open-grained;" they, therefore, require a filler in finishing. Such woods properly should be called coarse textured. "Fine grained" woods, similarly, should be called fine textured.

Texture also is often used to describe workability of wood with tools. Such terms as harsh or smooth texture and even or uneven texture are used frequently in describing wood qualities (50).

Grain is a term used to describe the alignment of wood elements in relation to the longitudinal axis. Wood is considered to have straight grain when elements are parallel to the longitudinal axis. When elements are sloped, wood is described as spiral grained. In many tropical woods and a few native species, spiral grain reverses at periodic intervals and produces a condition called interlocked grain. Undulations in wood elements are responsible for wavy or curly grain.

Grain also is used to describe arrangement of wood elements. When transition from springwood to summerwood is uniform and there is little difference between the two, wood is described as even-grained. When the transition is abrupt or the difference between springwood and summerwood is pronounced, wood is described as uneven-grained. Examples of uneven-grained wood are southern pine, hemlock, and oak. Examples of even-grained wood are maple, basswood, and white pine. Uneven grain frequently is associated with fast growth and occurs in wood near the pith.

Figure is a term applied to certain patterns formed naturally in wood; it may be enhanced by specialized cutting techniques that accentuate normal markings (28, 40, 44, 45, 46, 68). Many types of figure are described as optical illusions normally perceived by viewers. Figure also may be caused by uneven coloration resulting from pigmentation in wood.

In general, figure is not considered to be produced by normal methods of cutting lumber or veneer, **i.e.**, nested V-shaped lines on tangential faces produced by flat sawing or series of parallel lines on radial faces produced by quarter sawing (Figure 2). However, when figure caused by grain orientation is present, method of cutting becomes of great importance in development of a particular figure.

Figure Caused by Pigmentation

There are a few woods in which a well defined pattern, or figure, is developed because of uneven pigmentation (63). Color patterns appear as uneven streaks in figured red gum (21). Strongly contrasting colors may be concentrated in growth increments of a few tropical species such as zebra wood. Several other tropical woods belonging to the rosewood group exhibit variegated pigmentation, ranging in color from reddish brown to black, which produces figure patterns. Figure types caused by pigmentation lack the luster of figures caused by grain variations (23).

Figure Types Caused by Variations in Grain Orientation

The normal orientation of longitudinal cellular elements in wood is parallel to the longitudinal axis of the woody cylinder. Various deviations from the parallel develop a number of well defined figure patterns.

Certain portions of trees also play a major role in development of figure patterns in wood (Figure 3). These are defined as follows:

Longwood

The bole or stem (from stump to first limb or fork) produces the majority of wood. It normally is available up to 16 feet (4.88m) in length and may or may not exhibit patterns different from typical patterns found in flat or quarter-sawn lumber. This type of wood is used primarily for architectural installations and wall paneling. It may exhibit any or all common figure types in some areas, but generally shows little figure development (Figure 4).

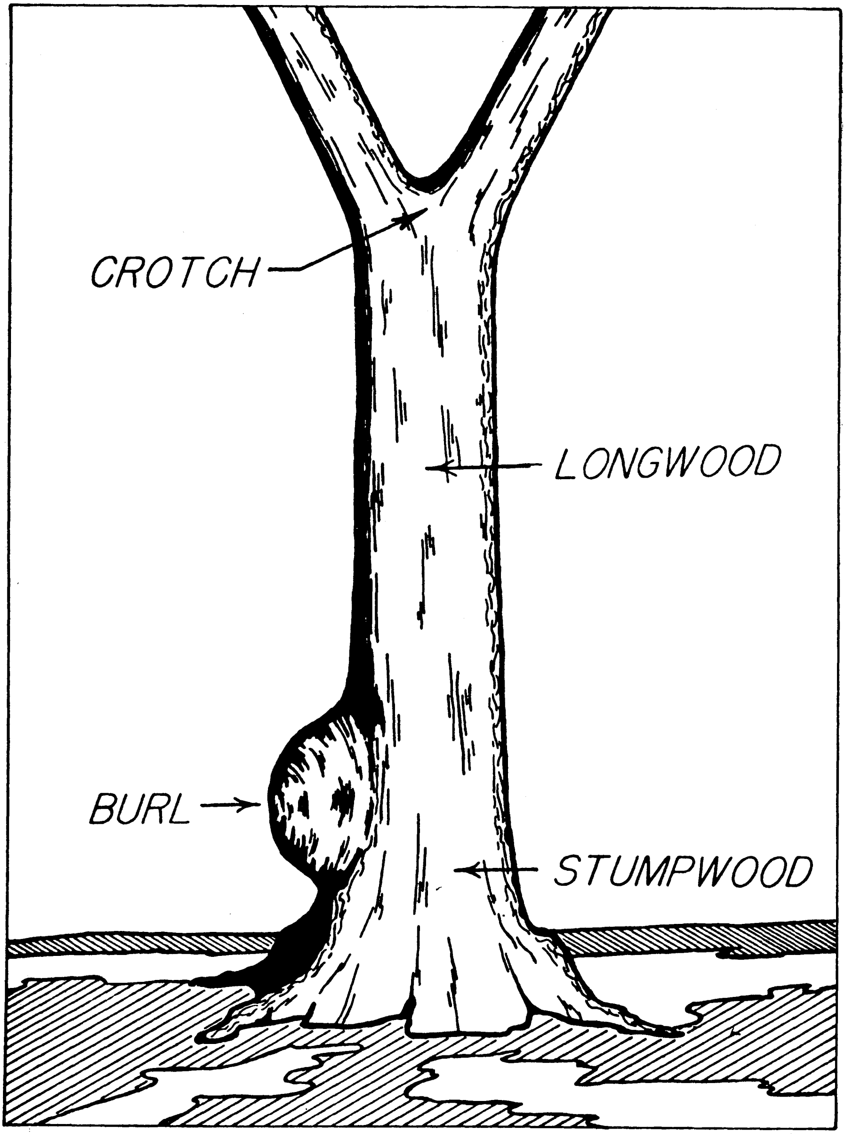


Figure 3. Specific tree locations where figured wood may occur.

Figure 4. Longwood of Japanese ash (tamo) that exhibits a slight blister figure (t).

Crotch

Crotch figures are characterized by feather-like patterns that are obtained by cutting through forks where main boles branch. They normally are obtained from walnut or mahogany and were used extensively in furniture during the 18th and 19th centuries. They seldom are seen today except in high grade gunstocks. Excessive end grain exposure and random orientations frequently cause crotch-figured wood to check severely. This type wood must be reinforced with backing to prevent such checking (Figure 5).

Stumpwood

As the name implies, this particular figure type is obtained from stumps. It seldom is seen except in walnut and is characterized by wrinkles and blotches of color variations. It is a very attractive figure that may be observed occasionally in furniture and gunstocks (Figure 6).

Burls

Burls are irregular, spherical growths that occasionally occur on trees near ground level (24, 53). They occur primarily on elm, walnut, maple, and redwood. Rarely do they occur commercially in other trees. Many of the most prized possessions of early emperors and kings were made from burlwood (53). Utilization of elm burls for furniture in the

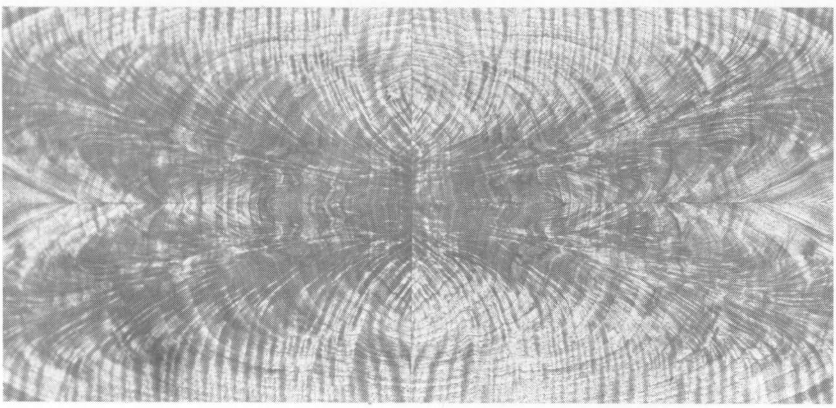


Figure 5. Four-way butt-matched walnut crotch table top (r) that shows a distinct feather-like pattern. (Photo: Fine Hardwoods Association)

Figure 6. Stumpwood figure of walnut that illustrates wrinkles and blotches of color variations (t).

U.S. during the 1920's probably led to introduction of Dutch elm disease into this country. *Ceratocystis ulmi* (causal fungus of Dutch elm disease) probably was introduced into this country within elm-burl material imported from France for use as veneer and subsequently in furniture manufacture. Burls are usually small and characterized by eye-like markings surrounded by swirls and distorted tissues. Burl tissue is soft and "velvet-like" to the touch (Figure 7).

Figure Caused by Ray Structure

Figure occasionally results from cutting wood so that rays are parallel to the wide face where a series of shiny, light-reflecting surfaces are formed (63). These are known as ray flecks. In such woods as the oaks *(Quercus)* or sycamore *(Platanus),* ray flecks are very pronounced and exhibit typical patterns (Figures 8 & 9).

Ray flecks are present in all woods and reach their greatest development in sections that are quarter sawn or sliced. They normally do not contribute materially to figure other than to produce a lustrous surface. However, some woods may exhibit conspicuous mottled figure caused by extra large rays (20).

SPECIFIC FIGURE IN WOOD

Specific figure in wood can be divided into three categories based upon the type of growth within trees that initiates the figure:

(1) Figure related to spiral growth;
(2) Figure related to undulating growth; and
(3) Figure related to indented growth rings.

Figure Related to Spiral Growth

Spiral Grain

As mentioned before, normal orientation of longitudinal cellular elements is parallel to the longitudinal axis (Figure 10). However, slight undetectable spiraling is a rule rather than an exception in most trees. In certain trees, elements are sloped or spiraled circumferentially to an extent sufficient to be detected. When wood with this characteristic is split, exposed surfaces will not be parallel to the longitudinal

Figure 7. Burl figure in Oregon maple that exhibits eye-like markings surrounded by swirls and distorted tissues (t). Curly figure appears in lower right.

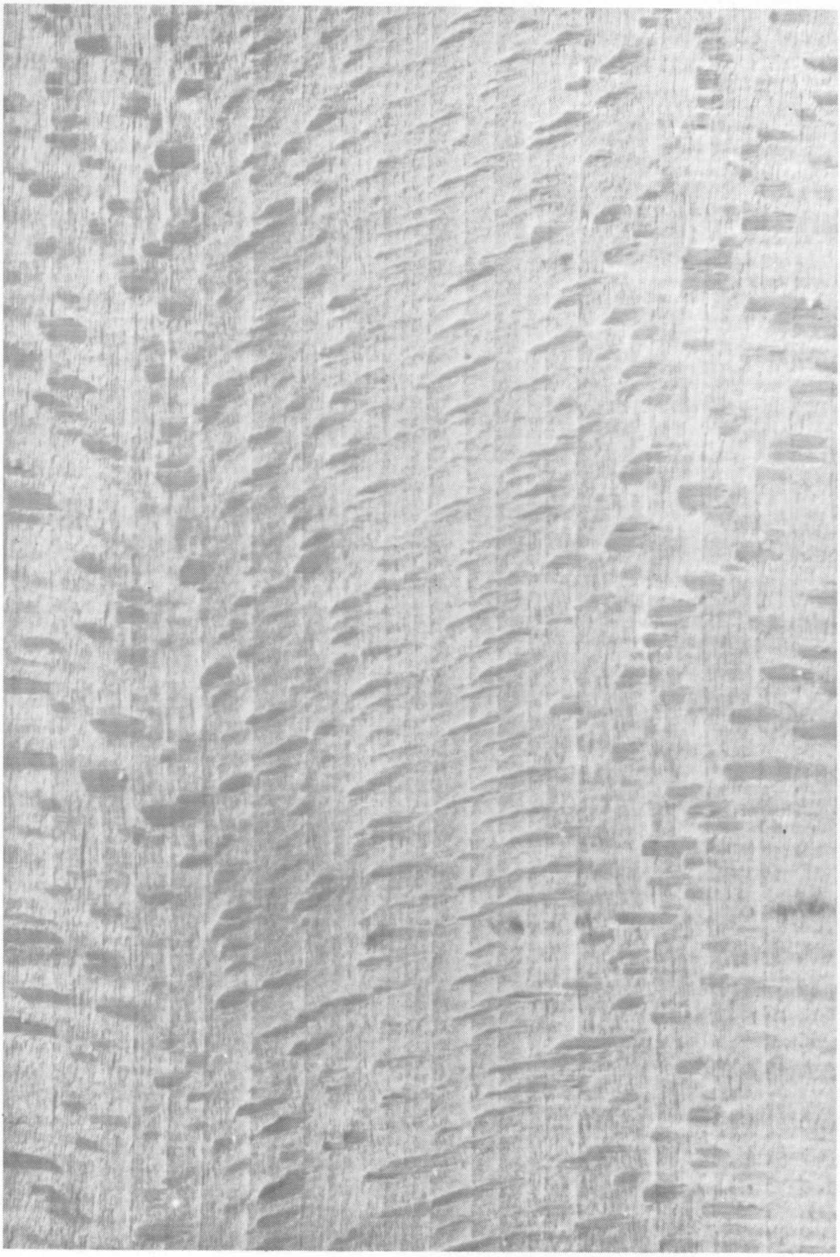


Figure 8. Typical ray-fleck figure in American sycamore (r).

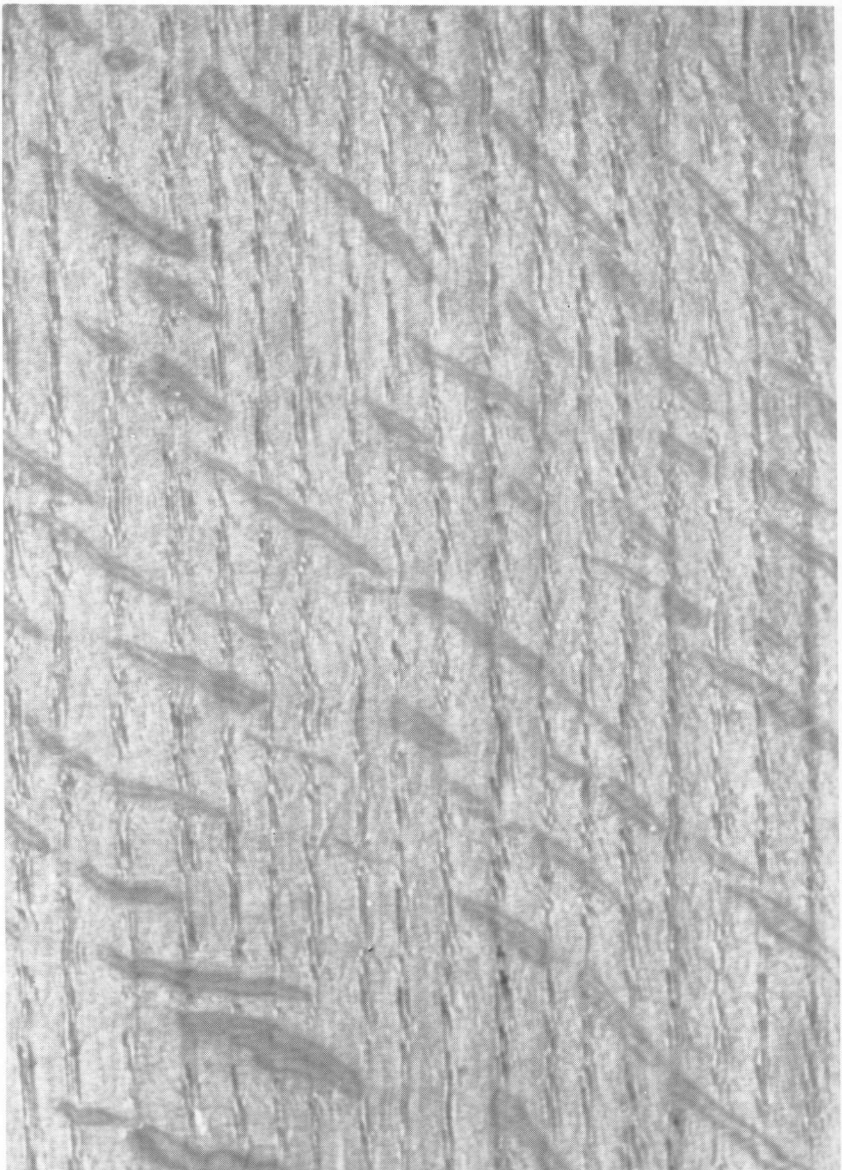


Figure 9. Typical ray-fleck figure in quarter-sawn oak (r).

axis as in straight-grained material (Figure 11). Spiral grain occurs quite commonly in certain species and is considered a defect in many cases (60, 85). Spiral grain in simple form does not cause figure since the surface reflects light rays at approximately the same angle at which

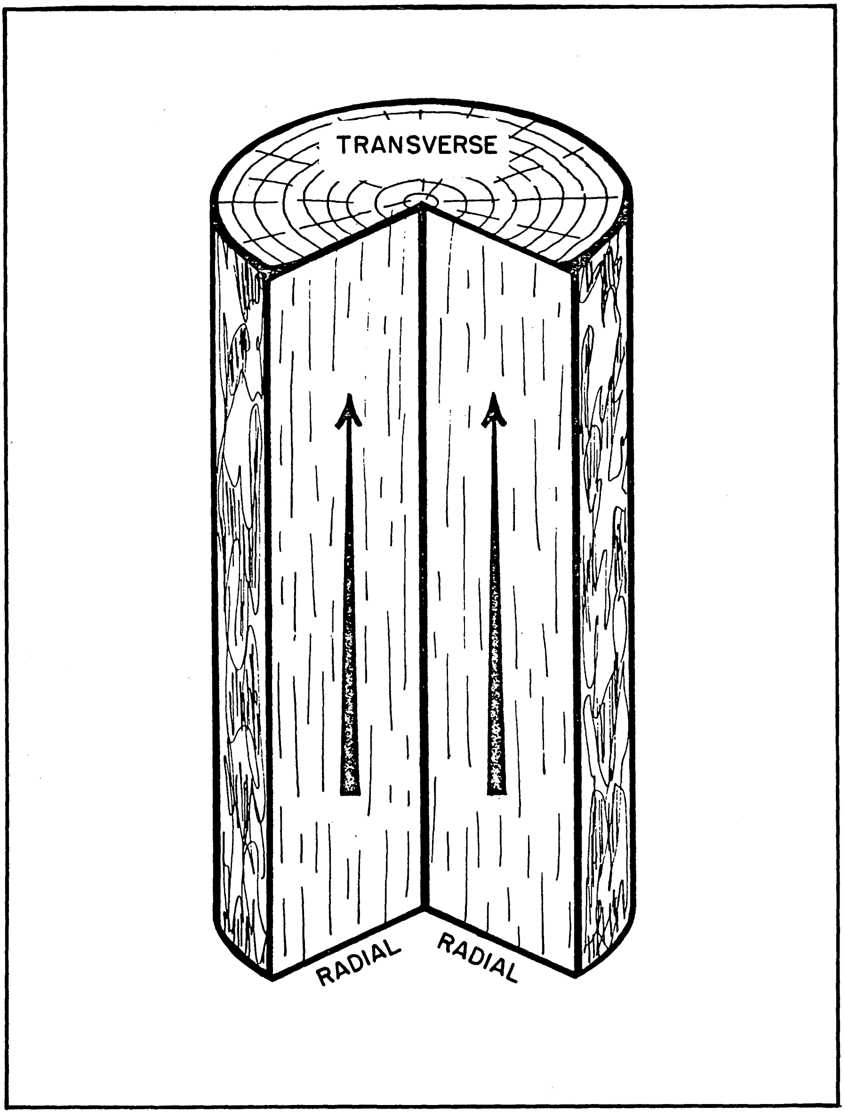


Figure 10. Diagrammatic split-log section (r) that exposes elements parallel to the longitudinal axis in straight-grained wood.

the rays strike. However, figure initiated by other causes may be enhanced by spiral grain.

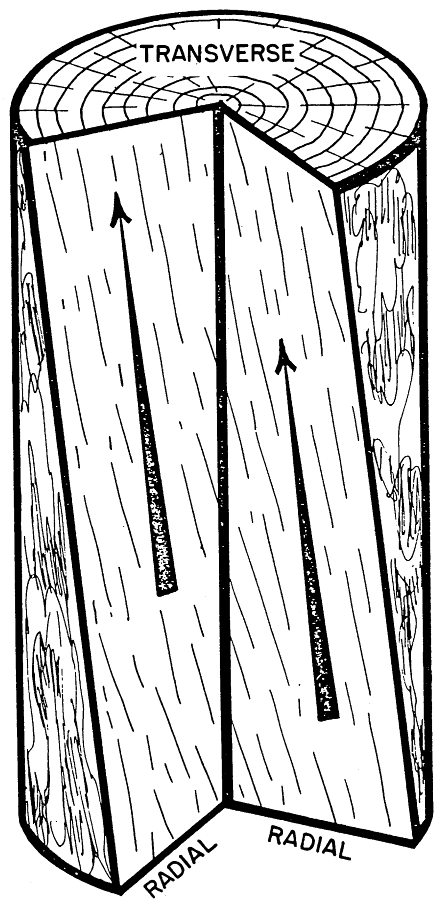


Figure 11. Diagrammatic split-log section (r) that exposes elements spirally aligned to the longitudinal axis. This condition is called spiral grain.

Interlocked Grain

Interlocked grain is a variation of spiral grain that is exhibited almost universally in tropical woods and in a few native hardwoods such as elms, gums, and sycamore (6). Interlocked grain is the cause of a particular figure type commonly called ribbon stripe or stripe figure.

Interlocked grain is spiral grain that is produced in one direction for a given period of time, then for some unknown cause is reversed with the same angle and is produced in the opposite direction for a similar length of time (Figure 12). This pattern is repeated many times throughout the tree life and results in a grain that is interlocked. Wood exhibiting interlocked grain is almost impossible to split.

When interlocked grain is produced uniformly and regularly in a given tree and the log is quarter sawn or sliced into veneer, a series of longitudinal parallel stripes is exhibited by the wood. These stripes alternate in color shades (dark, light, dark, light, *etc.*). When such wood is shifted slightly or turned end for end, the stripes will be reversed (light stripes become dark and dark stripes become light). An example of this phenomenon is shown in Figure 13.

Grain direction in such wood does not correspond to growth increments but is independent of them. Stripes are produced by the direction of fibrous elements being viewed either toward or away from the observer (Figure 14). In unilateral lighting, stripes that appear bright are those where grain is oriented away from a viewer and light is reflected back. In dark stripes, grain is oriented toward the observer and end grain is exposed that then absorbs light causing the stripe to appear darker. Turning the specimen end for end reverses the angle of elements in relation to the observer and they appear reversed. Any slight movement of light source, specimen, or angle of observation will change relative brightness of pattern.

A variation of stripe figure that sometimes occurs is that of the broken or interrupted stripe (Figure 15). This is caused by an indistinct interlocked grain in combination with poorly developed wavy grain.

Figure Related to Undulating Growth

In contrast to previous examples of spiral and interlocked grain, there are a number of figure types that are formed by grain which is straight in a sense that it is parallel to the longitudinal axis in whole perspective but undulating or wavy when viewed closely. Some of these are wavy in the radial plane while others are wavy in the tangential plane (22). Together they collectively are called wavy or curly grain, irrespective of the plane in which they occur.

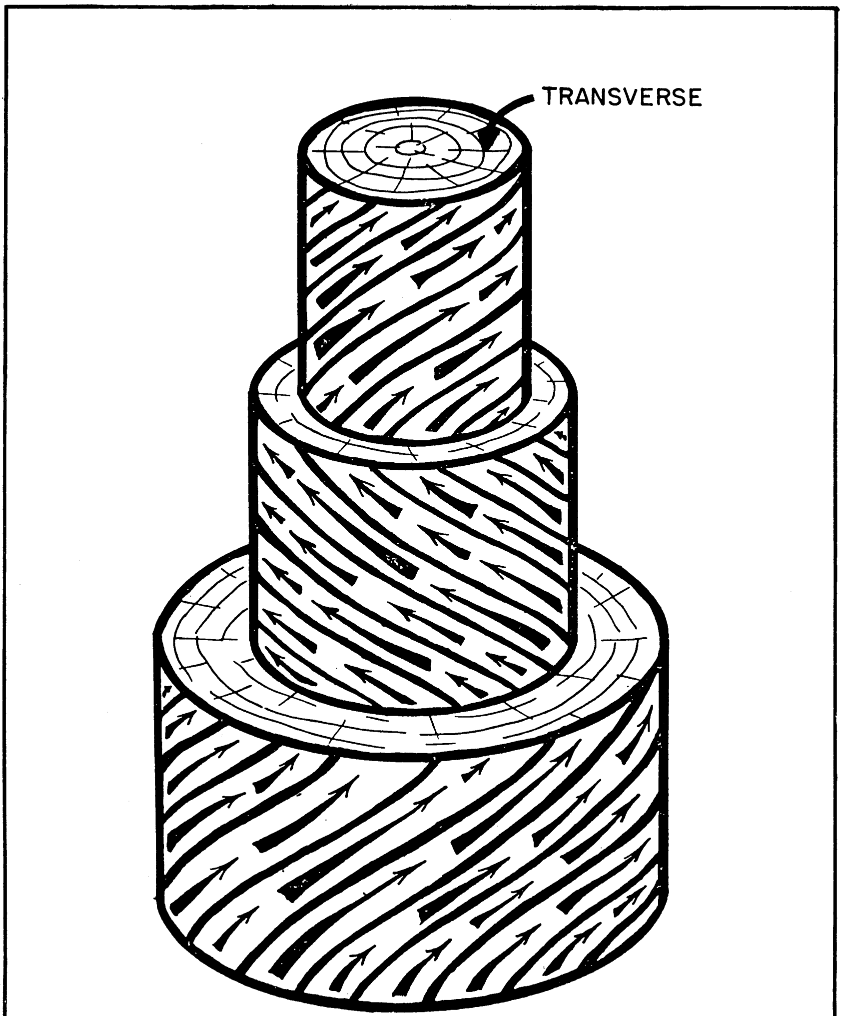


Figure 12. Diagrammatic log section that illustrates relative grain direction exhibited by interlocked-grain woods. Grain direction is independent of annular growth increments.

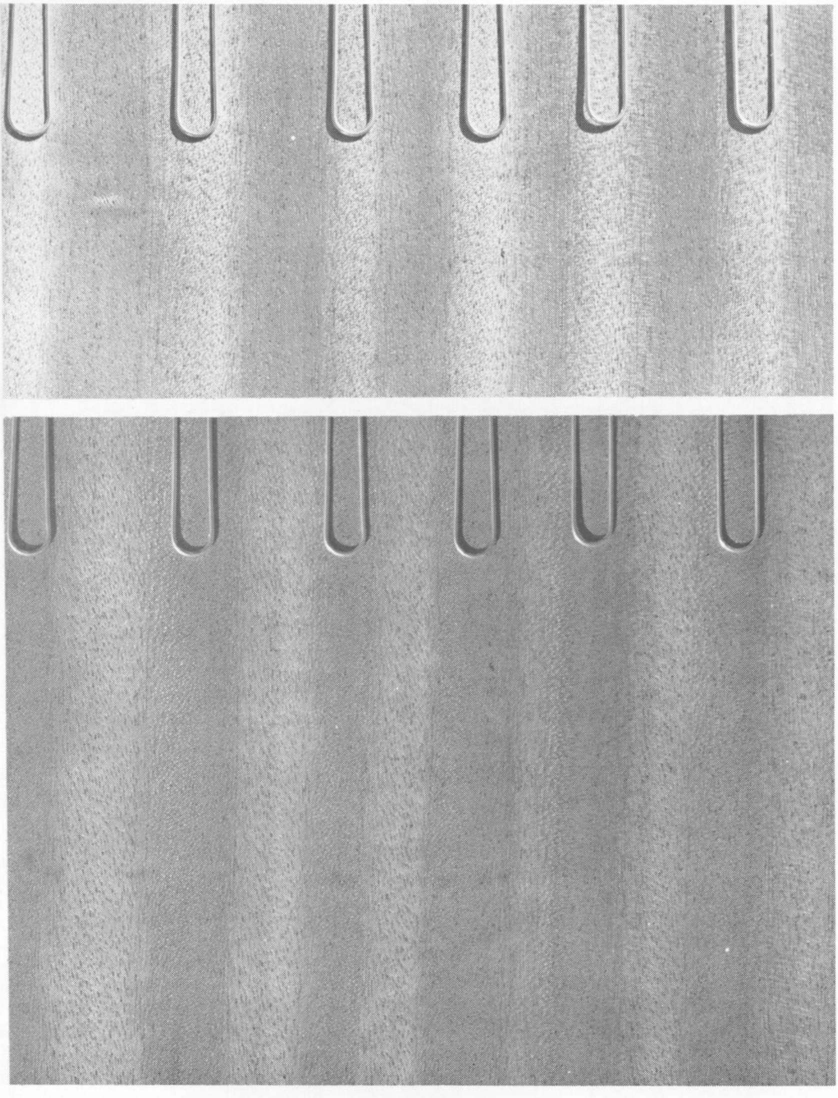


Figure 13. Ribbon stripe in the same piece of tigerwood veneer (r) that shows effect of light direction on appearance of stripes. Light direction can be determined by shadow direction from paper clips.

In a few cases, very sharp indentations occur where locally restricted growth produces circular or lenticular indentations in the tangential surface. Various names such as birdseye, dimple, bear scratches, *etc.* have been given to such figures based on size, shape, or form of the indentations (4, 63, 82).

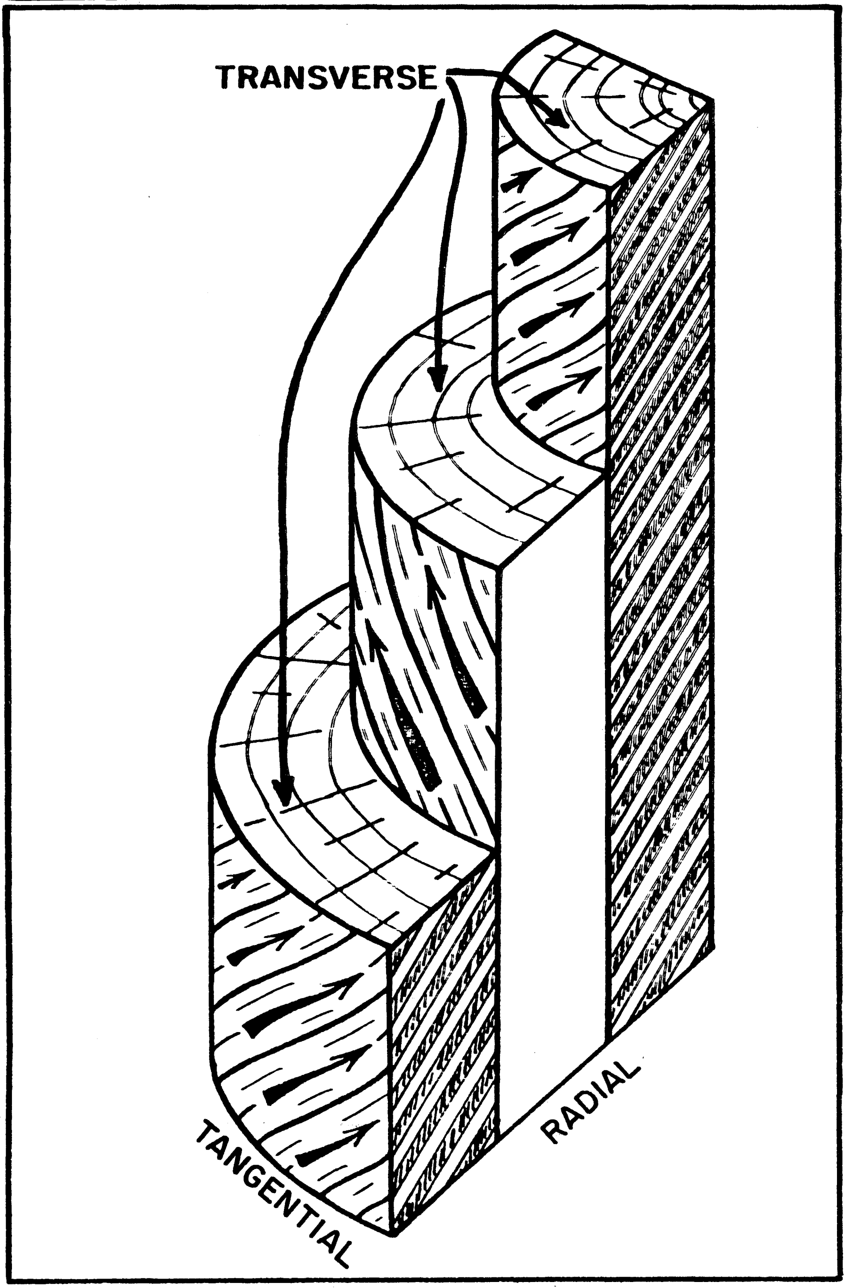


Figure 14. Diagrammatic section of interlocked grain that illustrates differential absorption and reflection of light by exposed end and side grain. Dark stripes are caused by light absorption in end grain while bright stripes are caused by light reflection from sloping side grain.

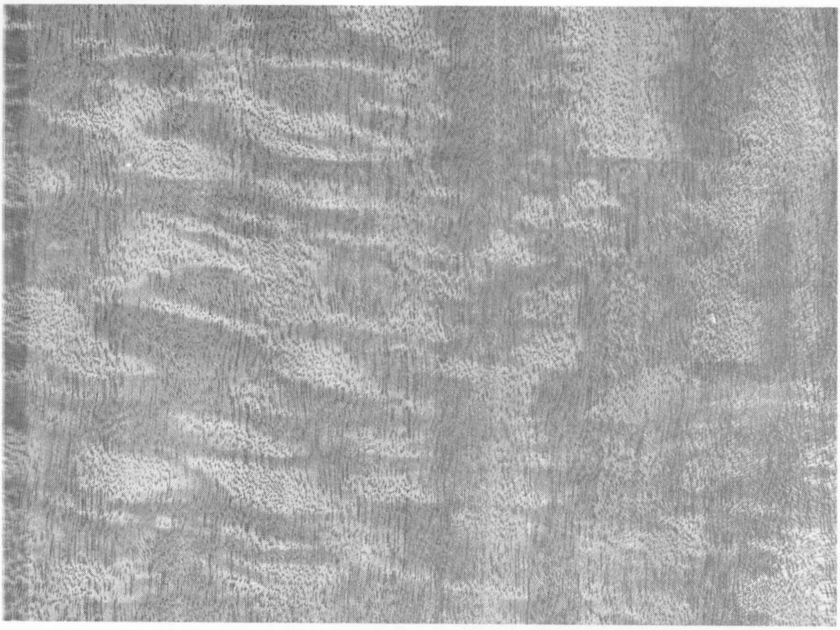


Figure 15. Broken-stripe pattern in Honduras mahogany (r). This figure is caused by a combination of interlocked and wavy grain.

Cause of undulating growth can be traced to the method of cell division and enlargement described later. On a larger scale, undulating grain can be observed to produce an interference pattern or "moiré" (wavy) figure that appears to the viewer as an optical illusion of movable stripes or contrasting patches of light and dark areas resulting from the fibrous structure (43).

Radial Surface — Curly and Fiddleback Figures

When the radial surface of wood exhibits wavy growth or grain, the tangential face is smooth and the wavy or undulating grain can be observed, but is not evident to the touch (Figure 16). When a wood section with curly grain is split, it separates along the rays and along the wavy grain and is exhibited as a corrugated surface that can be seen and felt on the radial surface (figures 17 and 18).

Well developed wavy grain is rare in trees of most species, but the figure is observed frequently in maple *(Acer),* ash *(Fraxinus),* birch *(Betula),* and walnut *(Juglans).* Wavy grain is quite common near limbs and roots, where it is localized in small areas. Wavy grain frequently is called "curly" when waves can be measured in terms of numbers per foot and "fiddleback" when waves are measured in numbers per inch (19, 77). True fiddleback is restricted to uniform, straight-grained

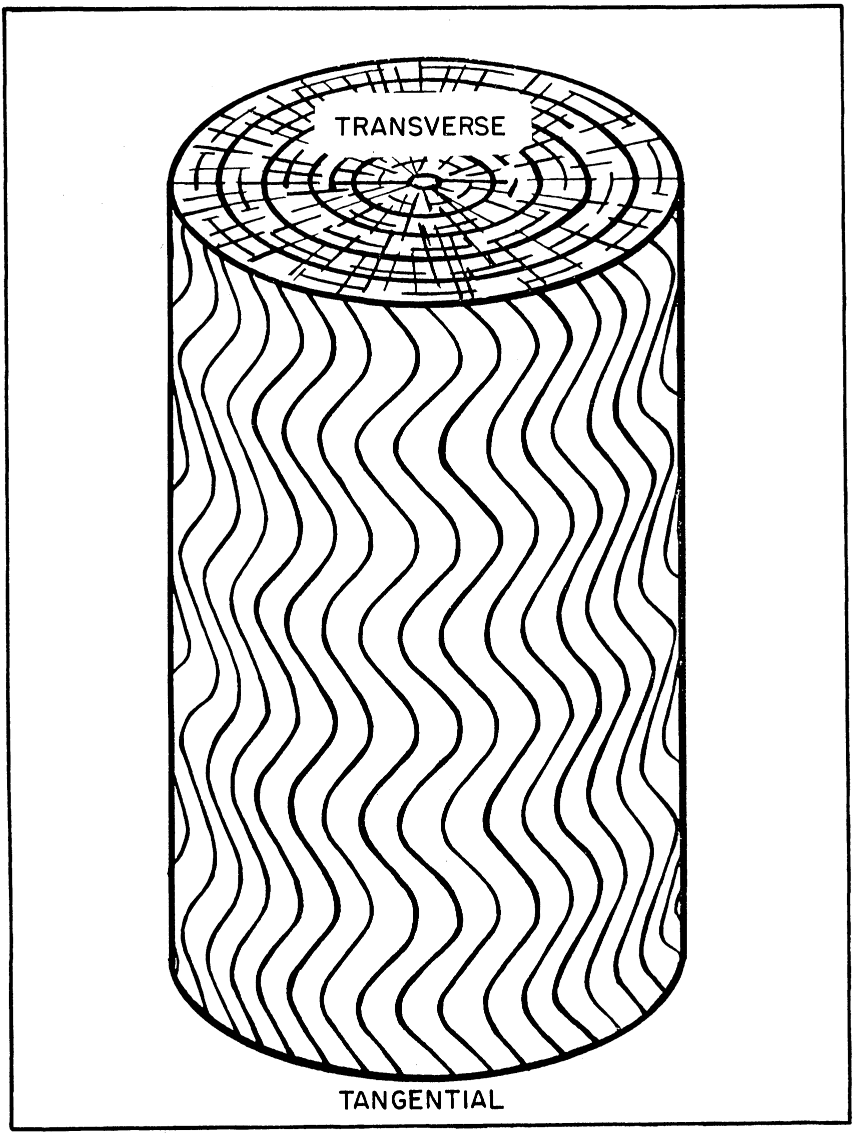


Figure 16. Diagrammatic log section that exhibits undulating growth in the radial plane as shown on the tangential surface. Note optical illusions giving a false appearance of circumferential bulges.

wood of high quality; curly woods frequently exhibit sloping grain and other defects (22). Trees are tested for evidence of curly/fiddleback

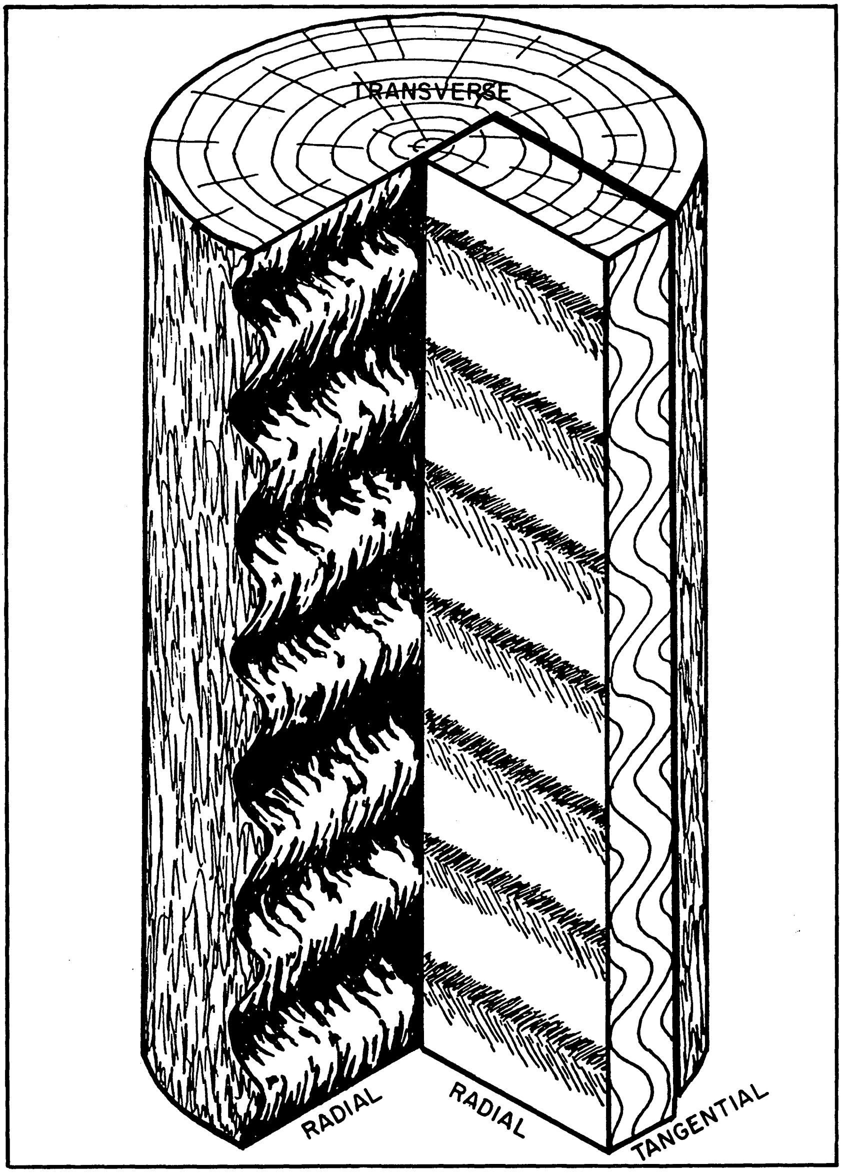


Figure 17. Diagrammatic log section shown in figure 16 that illustrates undulating growth (corrugated) on a split radial surface (LEFT) and a similar smooth-cut radial surface that shows a series of parallel, horizontal stripes (RIGHT).

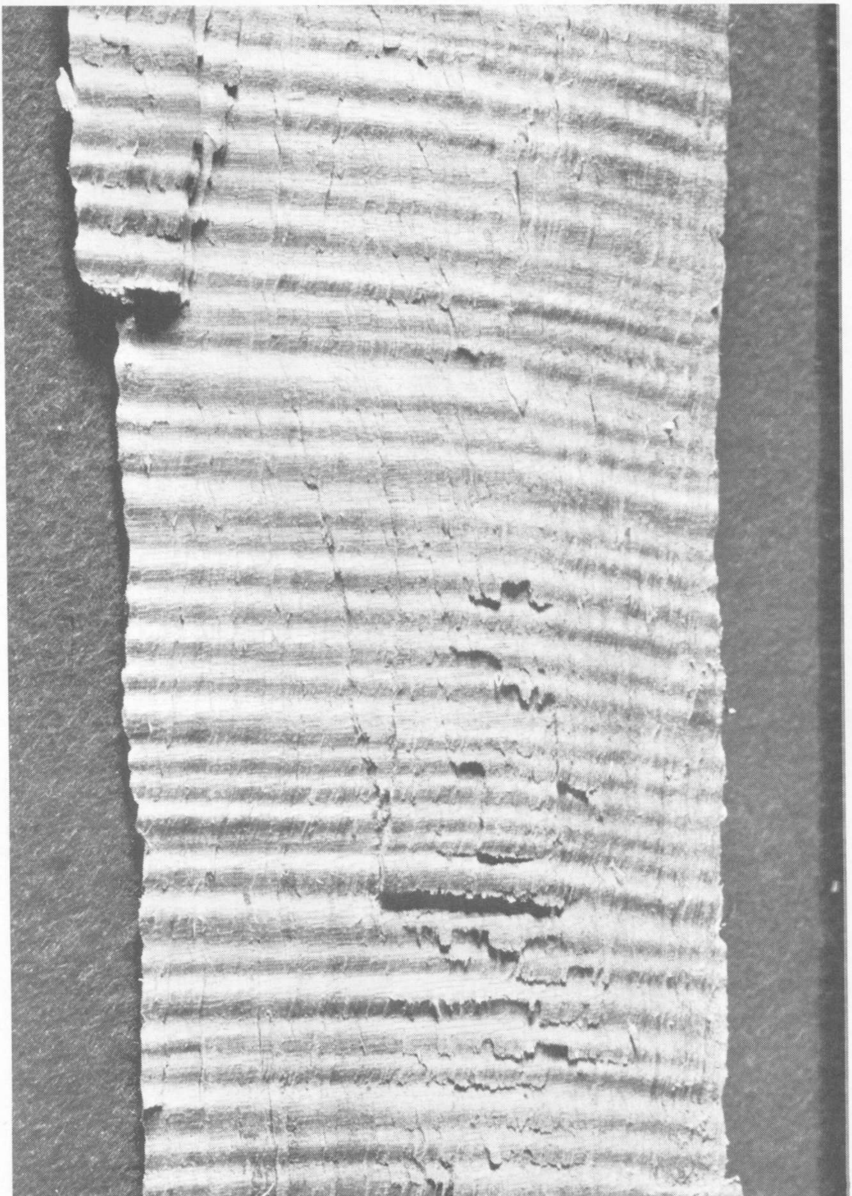


Figure 18. Split section of fiddleback figure in Oregon maple that shows a corrugated radial surface.

grain by chipping away the bark and examining the inner wood (Figure 1), as described previously. Because curly/fiddleback figure is restricted primarily to the radial plane, trees with this type of figure do not exhibit any visible external evidence such as bulges, flutes, or bark irregularities (figures 16 and 17).

Wood with curly or fiddleback figure commonly is cut in a manner to display a radial surface, which would be corrugated if the wood had been split (Figure 18). Appearing on smooth surfaces in place of waves are series of alternately bright and dark stripes that shade into one another and produce an illusion of actual waves. Changes in brightness result from differential light reflection. Relatively high absorption by exposed fiber ends produces dark bands; reflection and diffraction from fiber walls cause bright bands (Figure 19). Because the fiber walls are curved sharply and act as concave or convex reflecting surfaces, any change in angle of view or incident light makes the apparent waves seem to shift. Tangential surfaces present much the same appearance (Figure 20). The illusion of undulations, however, results from regular and repeated, parallel, wavy lines that produce an interference pattern on the exposed plane (Figure 16).

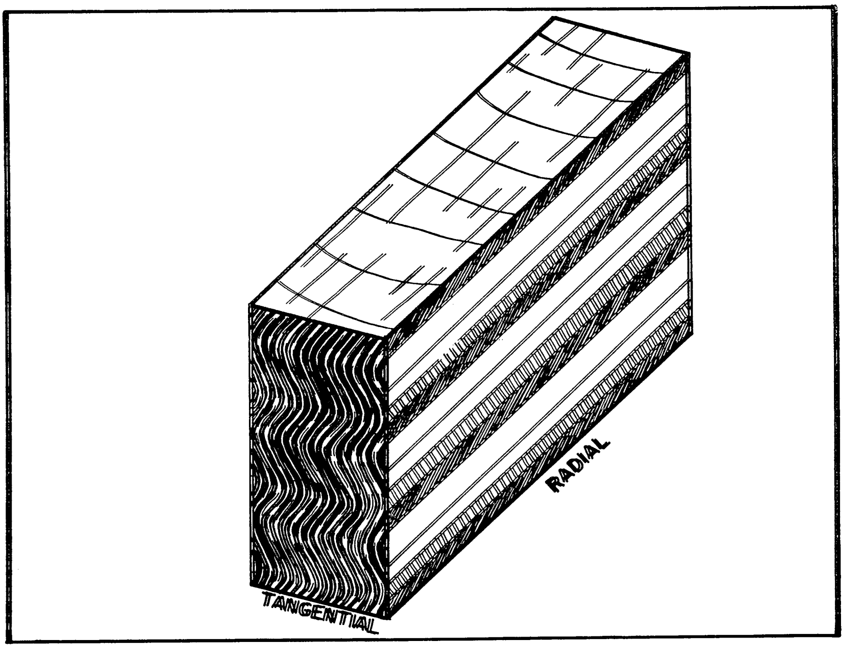


Figure 19. Diagrammatic wood section with undulating grain that exhibits sharp bending of elements and its effect upon reflection and absorption of light. Exposed grain areas appear as dark and light stripes depending upon the angles of observation and light incidence.

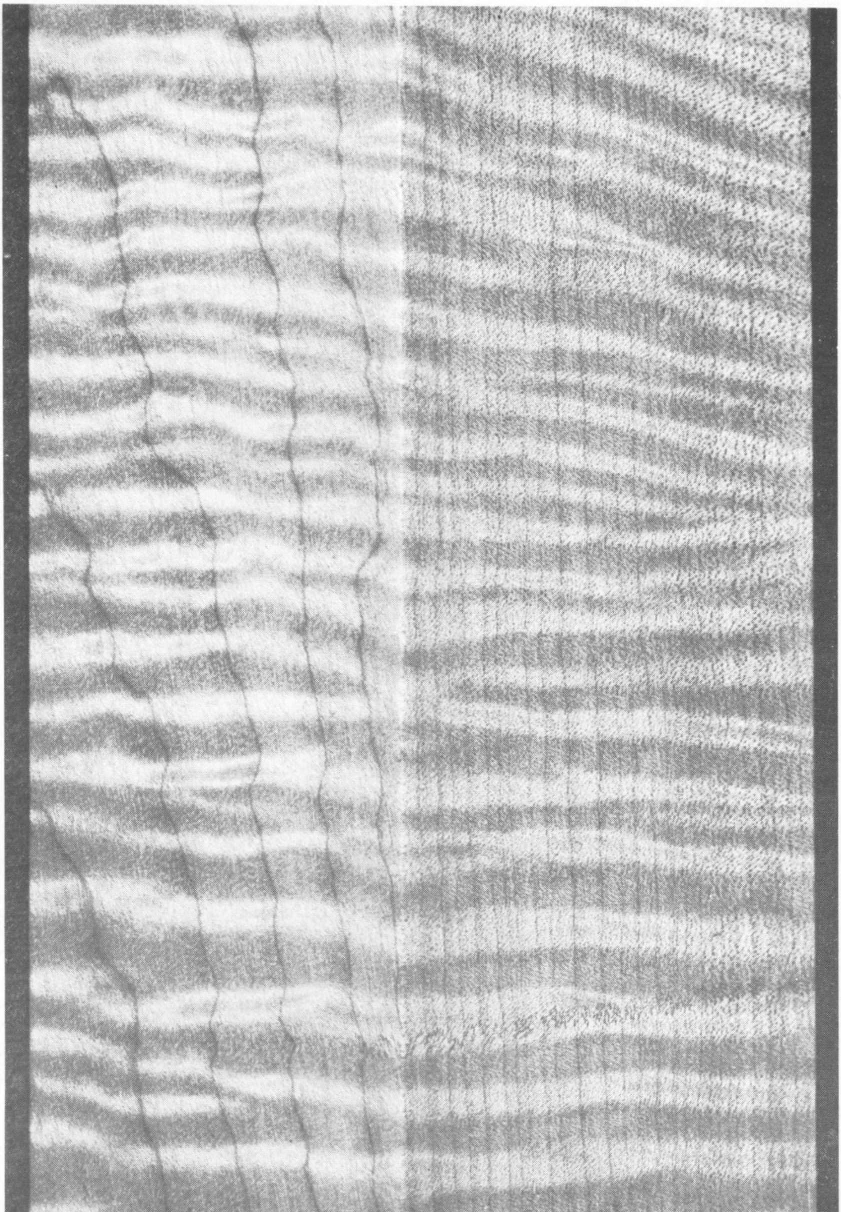


Figure 20. High quality fiddleback figure in Oregon maple that illustrates a true fiddleback figure in the radial plane (RIGHT) and an illusion of figure in the tangential face (LEFT). Note the apparent branching of stripes. The actual figure and the figure illusion are equally pronounced.

When cut on the true quarter, fiddleback figure will show as a series of straight, evenly spaced, horizontal or slightly canted stripes. When cut slightly off true quarter, these stripes may appear wavy or branched. The latter effect is a result of interference patterns rather than differential light reflection and diffraction. Reversing the direction of viewing will reverse the bright and dark pattern.

The name "fiddleback" is derived from extensive use of this type of wood for backs of string and fretted instruments since the mid-sixteenth century. However, not all instruments were made with fiddleback figured wood. Even the great luthier, Stradivari, made some instruments with plain wood (figures 21 and 22). Stripes are sometimes simulated through various techniques to give a reasonable facsimile of true fiddleback figure (Figure 23). Simulated figure may be detected easily because it does not extend completely through the piece (Figure 24).

The preferred wood for musical instrument manufacture is Euro-

Figure 21. Three views of the "Spanish" Stradivarius made in 1723. This instrument is a typical example of a well-flamed, two-piece back. (Photo: Wurlitzer Collection)

pean sycamore *(Acer pseudoplatanus* L.) instead of the native sugar maple because of the greater density of the latter.

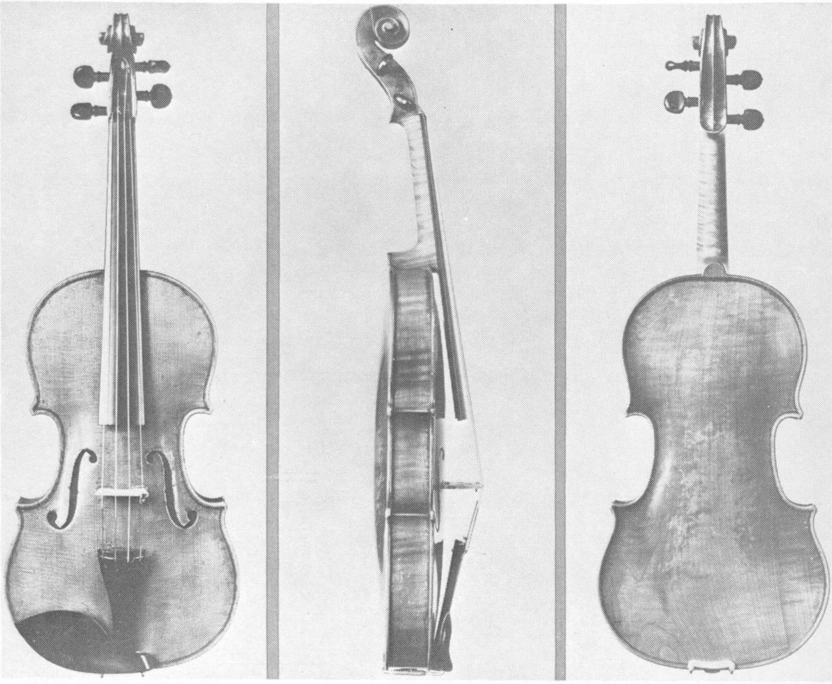


Figure 22. Three views of the "Ames" Stradivarius made in 1734. This instrument has a plain one-piece slab back. (Photo: Wurlitzer Collection)

Tangential Surface Blister and Quilted Figures

Curly or wavy grain occasionally affects the tangential surface instead of the radial surface (8). When this occurs, the effect rarely may be indicated by a series of irregular annual bark bulges. External evidence of figure, however,usually is not visible through the bark. Birch *(Betula)* exhibits this figure occasionally, and debarked logs may resemble a corrugated drainage pipe (58). A similar figure in some species of pine (29) is observed but rarely (figures 25 and 26). Tangential surfaces (circumference) exhibit a series of bumps and flat areas occurring in an irregular pattern. Bumps may enlarge and coalesce; then the junction between adjacent bulges is reduced to a line (figures 27 and 28). Rounded figures are designated "blister" (Figure 27); rectangular figures which

Figure 23. A violin back that illustrates a simulated fiddleback figure produced by staining (other types may be produced by acid etching or flaming).

Figure 24. The inner-back surface of the instrument shown is Figure 23. Note the absence of fiddleback figure. Ray-fleck pattern is evident.

usually result from coalescense, are designated "quilted" (Figure 28).

To develop blister and quilted figure, lumber must be flat sawn, and veneer rotary cut, because the figure occurs on the tangential face. Both lumber and veneer with blister or quilted figure differ from other figure types in that the front, or outside face shows an apparent series of mounds (convex areas) where the back face shows a similar series of concave or depressed areas. The results of "book matching"[3] the pattern are therefore unsatisfactory (Figure 29).

Well-developed blister and curly figures seldom occur in the same tree. However, several other imperfectly formed figure types (some commonly called "ghost" figures) occur more frequently together and this results in confusion of terms.

Figures Related to Indented Growth Rings

A third type of figure that is recognized originates from indented growth rings. In this class fall such figures as dimple, birdseye, and indented ring or "bear scratches." For unknown causes certain specimens of Douglas fir, lodgepole pine, sugar maple, Sitka spruce, birch, and mahogany exhibit reduced growth in localized circular or lenticular

[3]Two opposing cut surfaces turned as pages of a book and used side-by-side to yield bilaterally symmetrical patterns.

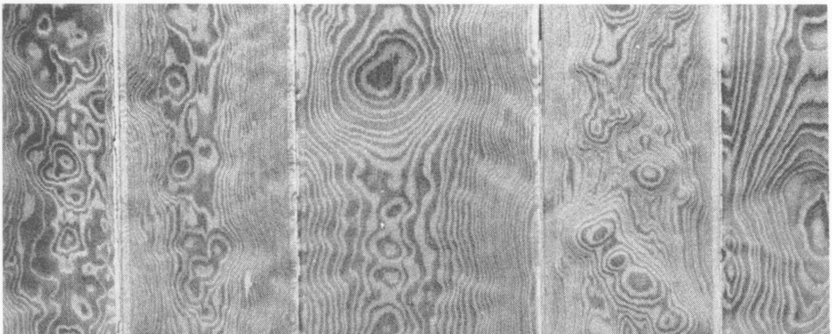


Figure 25. Wall paneling of curly southern yellow pine that shows typical blister figure characteristic of these woods (t).

areas that, continued year after year in the same location, results in circular or lenticular depressions in the wood (figures 30 and 31).

Indented ring figures affect only the tangential surface but differ from other figure types affecting this surface (blister figures) because they are formed primarily by sharp, conical or lenticular depressions indented toward the pith. This contrasts with blister figure, where major affected areas bulge toward the bark.

Dimple

Indentations in growth rings that create numerous localized, conical depressions that are small and shallow (usually less than one growth ring), are termed dimples (17). Tangential surfaces of wood from lodgepole pine *(Pinus contorta)* characteristically exhibit dimples (Figure 32), which are useful in identification.

Figure 26. Conference table constructed from curly southern yellow pine (t).

Birdseye

Indentations that create less numerous localized, conical depressions that are larger and deeper (usually one or more growth rings), are termed birdseyes. Birdseye of sugar maple *(Acer saccharum)* is the best known of indented ring figures (Figure 33). Birdseye figure has been reported in a number of other species including ash, walnut, and birch; in Cuban mahogany *(Sweitenia mahogani),* it takes the form of a giant birdseye (59).

Birdseye figure in sugar maple apparently occurs rather commonly but is well developed only in localized areas of the stem. Veneer manufacturers report that this figure may disappear completely as peeling progresses and reappear in different stem areas (11).

Split sections of birdseye figured sugar maple show sharp, conical indentations in the tangential surface. These indentations seldom exceed one-sixteenth inch in depth, usually occur in a random pattern, and may vary considerably in size and distribution among trees. Birdseye frequently occurs in combination with wavy or curly grain, which enhances the appearance. A characteristic of birdseye figure is its continuation along the same radius for a number of years. Birdseye figure is formed as a result of local suppressions in divisions of cambial tissues that cause indentations to develop. This retardation effect continues for several growing seasons and produces an indented conical depression.

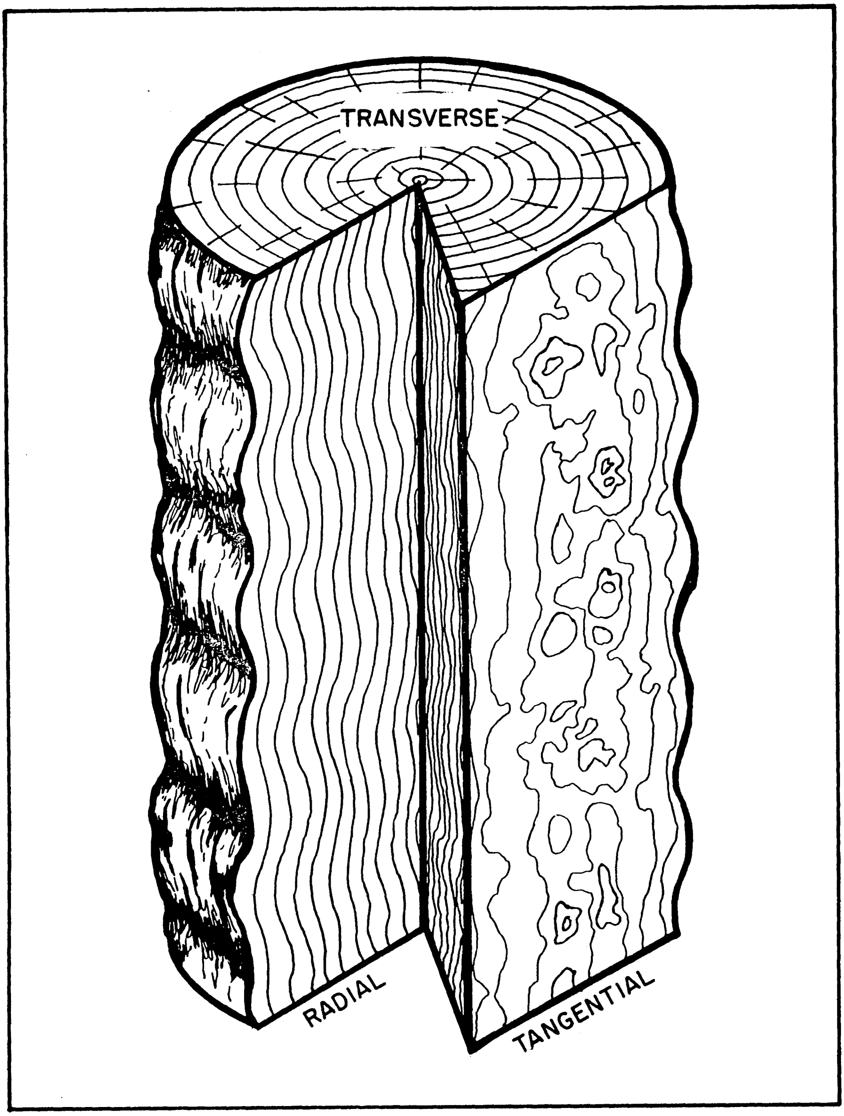


Figure 27. Diagrammatic log section that illustrates typical blister formation and pattern (t). Note undulating elements in tangential surface in contrast to those shown in figures 16 and 17.

Bear Scratches

Indented growth rings in the form of elongated or lenticular depressions are termed "bear scratches." Bear scratches occur most commonly in Sitka spruce *(Picea sitchensis)* and Douglas fir *(Pseudotsuga*

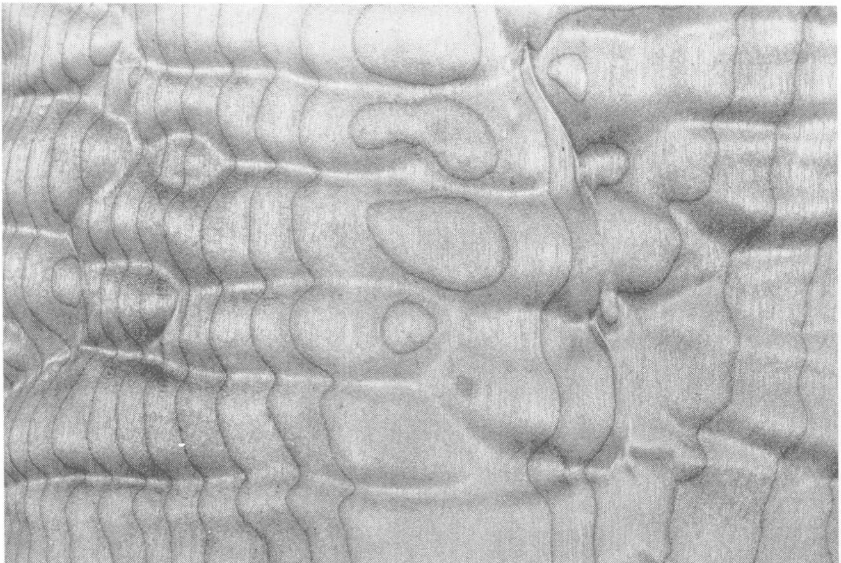
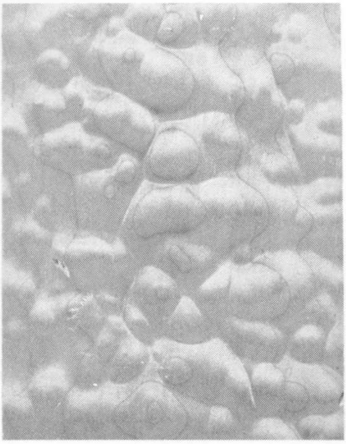


Figure 28. An excellent example of quilted figure in a bigleaf maple board that exhibits the characteristic rectangular pattern (t). Note the 3-dimensional appearance of flat surface. (Material: N. H. Beer & Associates)



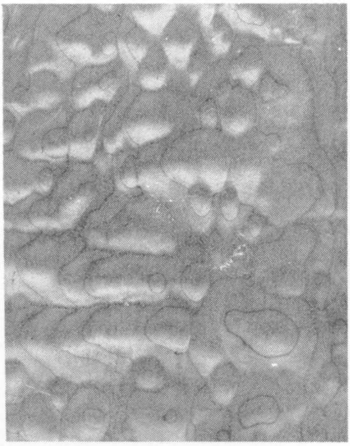


Figure 29. Front and reverse views of an Oregon maple board with typical blister figure. Pattern reversal is indicated by bulges on one face (LEFT) and depressions on the other (RIGHT).

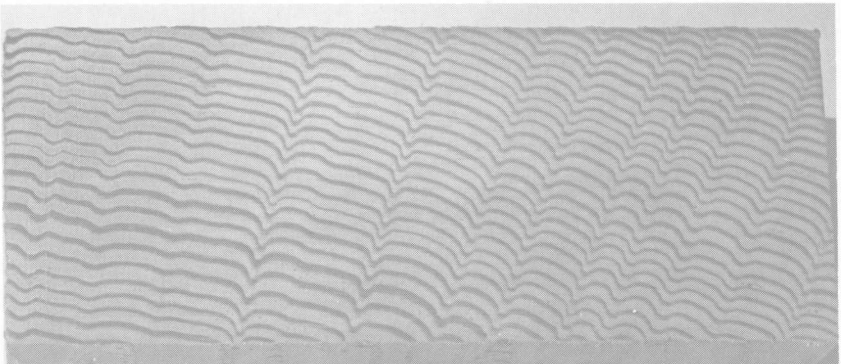


Figure 30. Transverse section of Douglas fir that illustrates typical indented-ring pattern. Bear-scratch pattern on longitudinal faces originates from these indentations.

menziesii). The term is derived from the appearance of lighter colored tissues that form longitudinal streaks on the tangential face. For many years, such streaks were thought to be caused by animal claw injury.

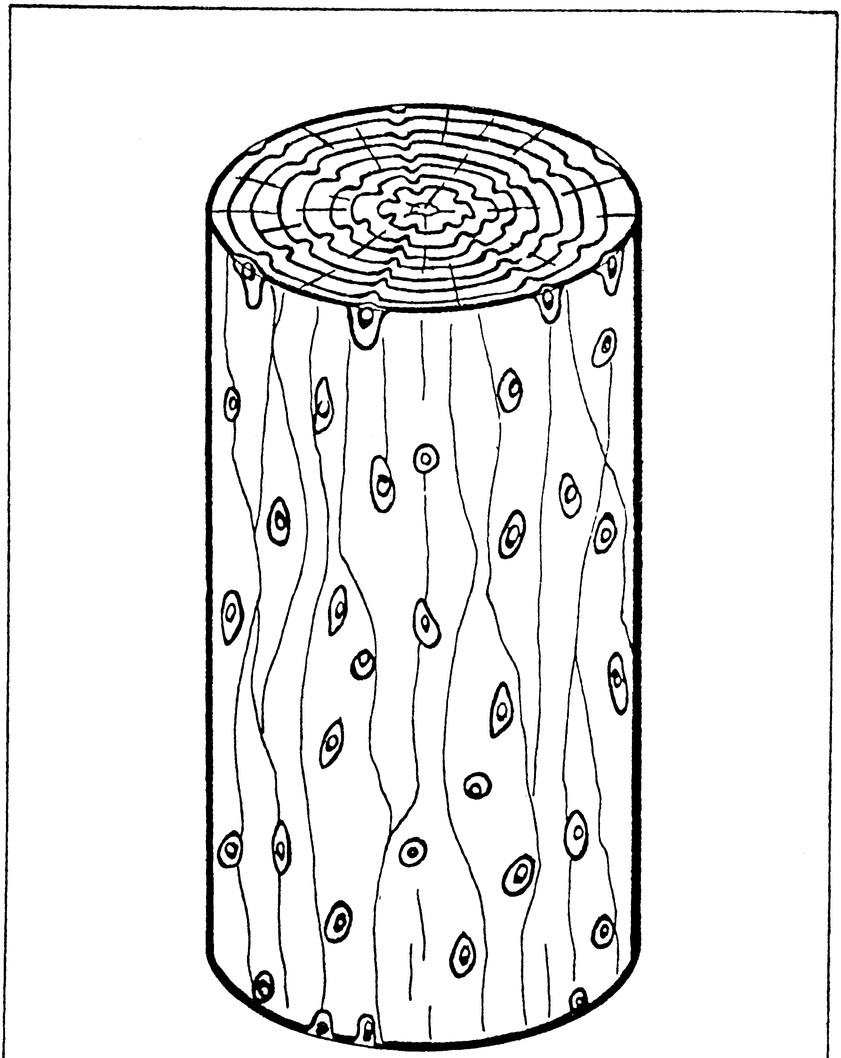


Figure 31. Diagrammatic log section that shows circular growth ring depressions in the transverse and tangential faces. Birdseye and dimple figure are initiated similarly by such indentations.

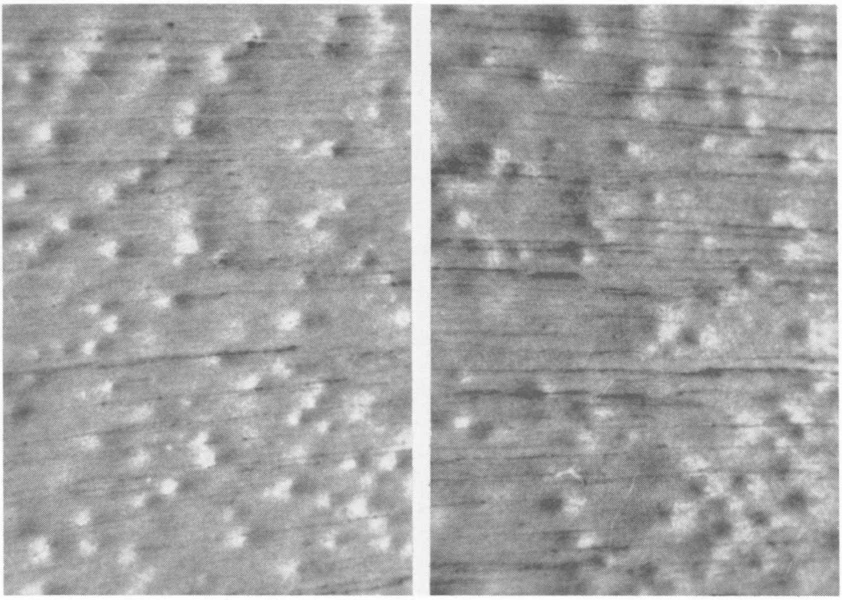


Figure 32. Split-block surfaces (t) of lodgepole pine that exhibit dimple figure characteristic of this species.

Figure 33. Birdseye figure of sugar maple in a veneer section (t) that illustrates typical figure pattern.

INITIATION OF FIGURE

Anatomical

Since the development and anatomy of unfigured wood are outside the scope of this publication, interested readers are referred to the "Textbook of Wood Technology, Vol. I" (63). Phases of figure formation that differ from normal development are described.

Spiral Growth

Spiral growth apparently originates from a modified anticlinal division of cambial initials that develops an organized intrusive growth, which results in a helical orientation (either right or left) of the cambial initials and in subsequent woody tissues. Helical or spiral orientation of elements in mature woody stems causes a twisted appearance. Certain tree species characteristically have elements that spiral to the right; others, to the left. Still other species exhibit regular alternation of spiral direction in successive growth increments to form interlocked grain. The variations appear to be largely hereditary within species. Many tropical woods exhibit interlocked grain so regularly that straight grain is considered unusual.

Undulating Growth

After initiation by cambial division, cells enlarge first by elongation and reach final size after differentiation. Elongation of individual cells initiated at the same time is sometimes delayed, resulting in some that are longer than others. Cells that are somewhat slower in elongation are restricted in available space, particularly when the ends are held rigidly in place. As cell elongation continues, central portions are pushed to either side resulting in a sinuous grain orientation. A certain amount of intrusive growth occurs where enlongating tips of adjacent cells force their way between cells lying above and below, particularly between ray cells (figures 34 and 35). This penetration evidently takes place while the intruding cell is relatively undifferentiated. After intrusive growth has occurred, the cell may become a vessel, fiber, or other element and continues to enlarge normally (figures 36 and 37). Such enlargement may result in lateral displacement of tissues, which appears to be the primary method by which the radial plane is affected. Lateral displacement also may affect the tangential plane (figures 38 and 39).

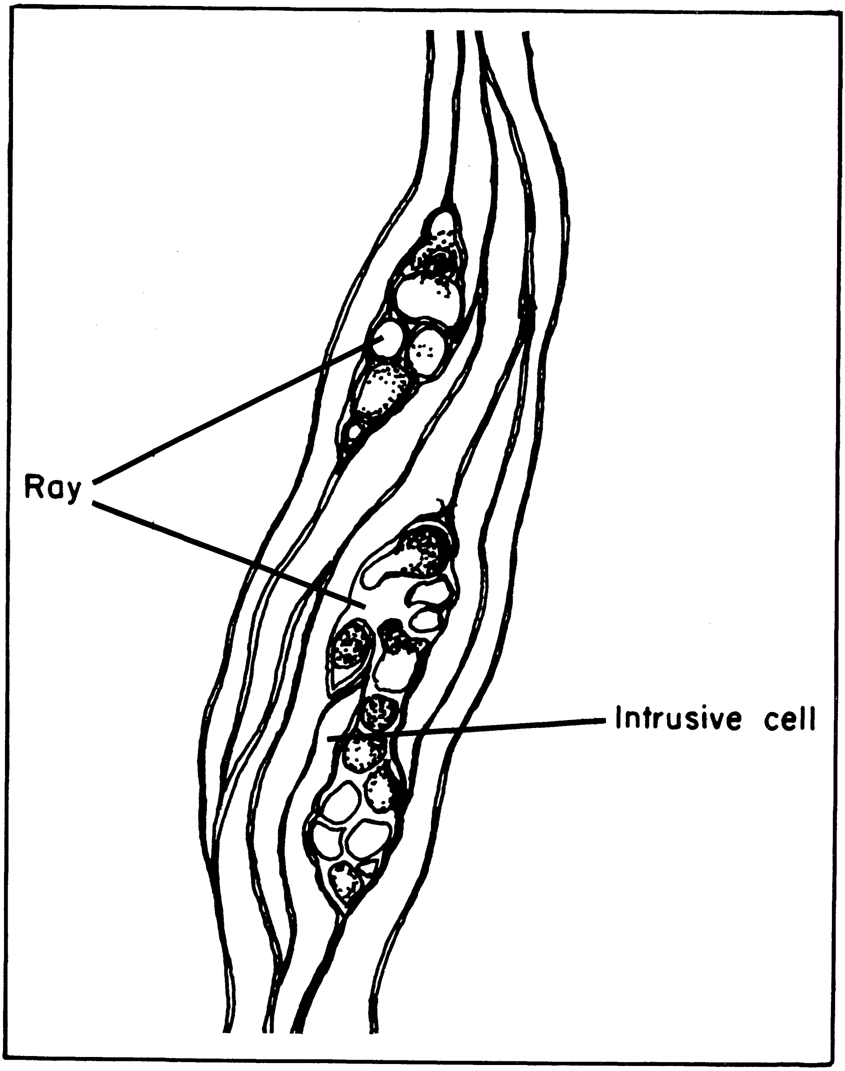


Figure 34. Early stage of intrusive growth of an undifferentiated cell penetrating into a ray (t). Such intrusive growth can initiate figure.

Indented Growth Rings — Indentations in growth rings have been traced to localized suppression of growth, where individual cell elements are bent sharply to conform with resulting depressions. In a few cases, however, the indentations appear to be localized areas of normal growth surrounded by areas of exceptionally rapid growth. Relatively smaller areas of stimulated growth result in bulges characteristic of blister figures.

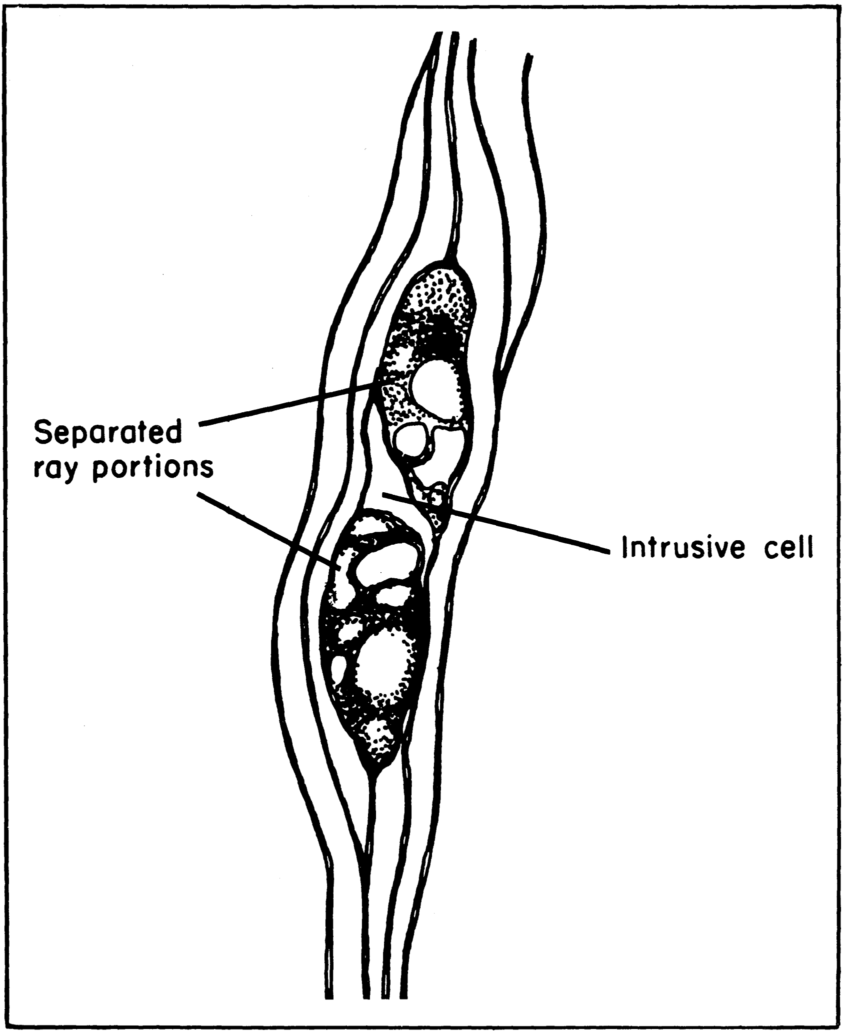


Figure 35. Later stage of intrusive growth of an undifferentiated cell into a ray where the ray has been forcibly separated (t).

Apparent lenticular depressions characterizing "masur" of European birch and "bear scratches" in other species exhibit parenchymateous tissues.

Possible Causes

The ultimate cause of figure in living trees is largely unknown. It has been suggested that stresses of various types of ranging from lean forces (forces produced in leaning trees) to unfavorable climatic conditions,

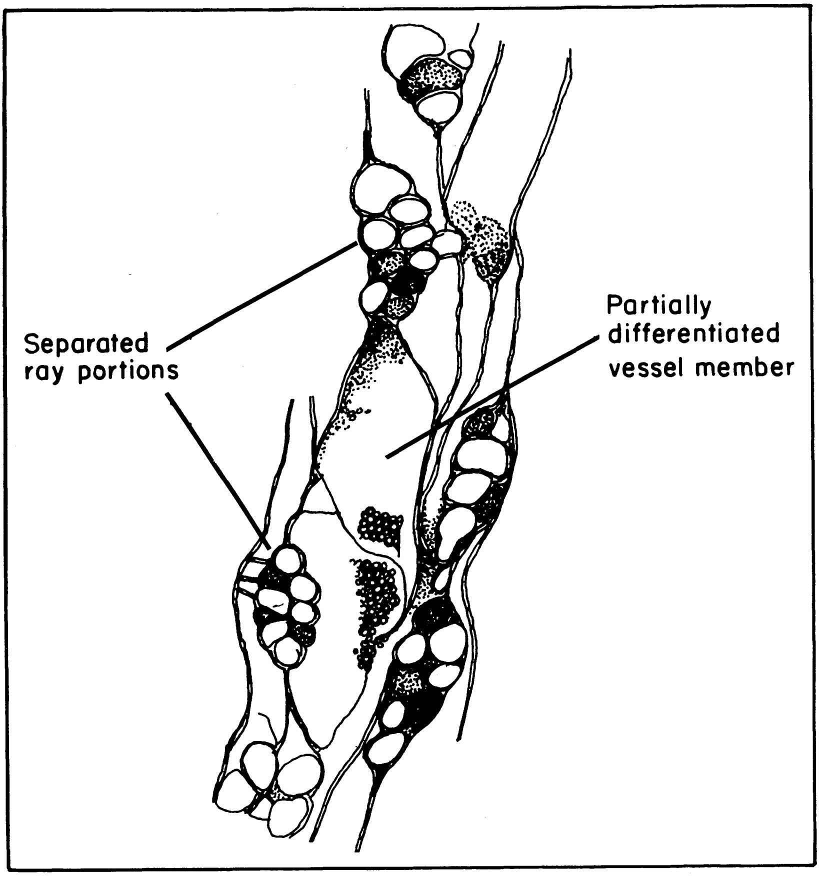


Figure 36. Advanced stage of intrusive growth of cell that has become partially differentiated into a vessel member (t).

disease, suppression, and several other factors contribute to figure formation (31).

Dormant buds acting over a considerable period of time have been suggested as causes of various birdseye and burl figures. Contrary to popular belief, birdseye figure has no connection with dormant buds. Splitting a block of wood containing birdseye serves to illustrate that indentations responsible for this figure point inward toward the pith and not outward toward the bark as would be the case with dormant buds (66).

During the early 1930's, considerable interest was stimulated concerning possible causes of birdseye figure in sugar maple and expressed through a number of publications in various journals that suggested suppression (34), heredity (35), or other factors (1, 69) as the cause. No formal studies were initiated, and interest apparently expired by the middle 1940's. An unpublished report concerning anatomy of birdseye

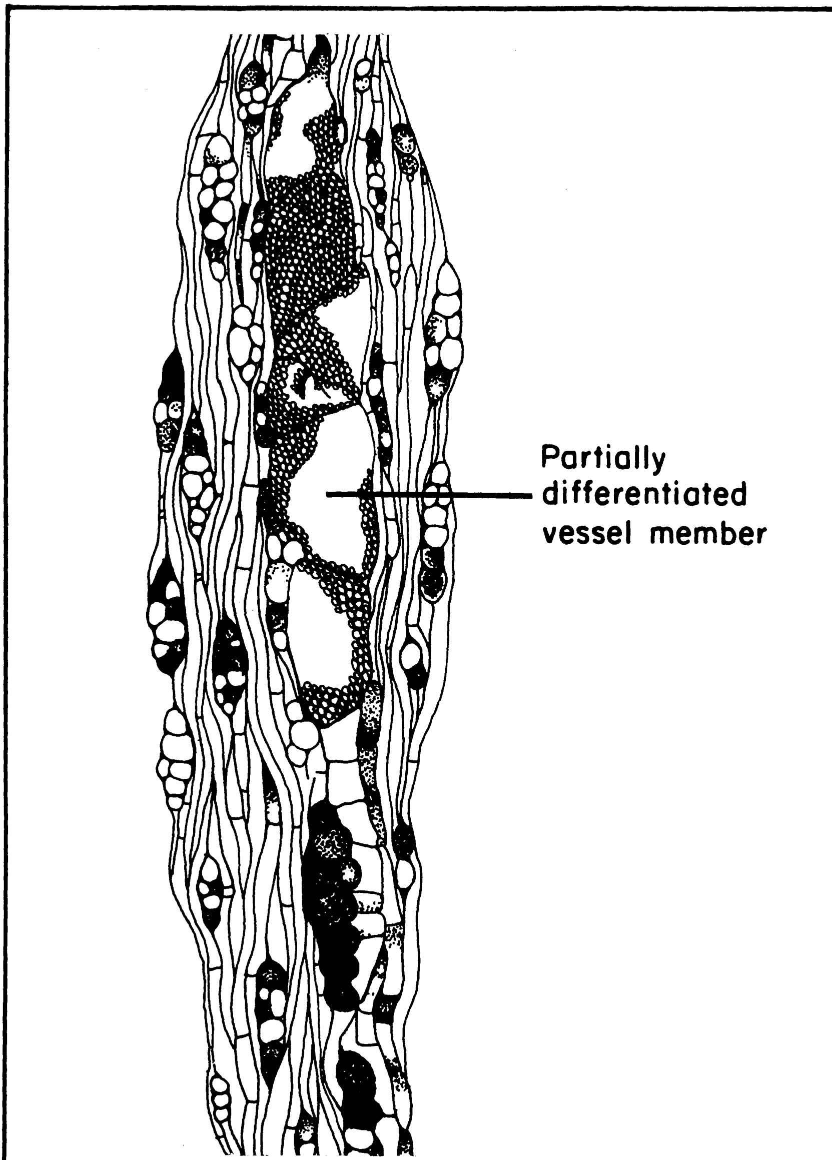


Figure 37. Partially differentiated vessel member that exhibits limited maturation (t). Note that cells below mature vessel elements remain undifferentiated.

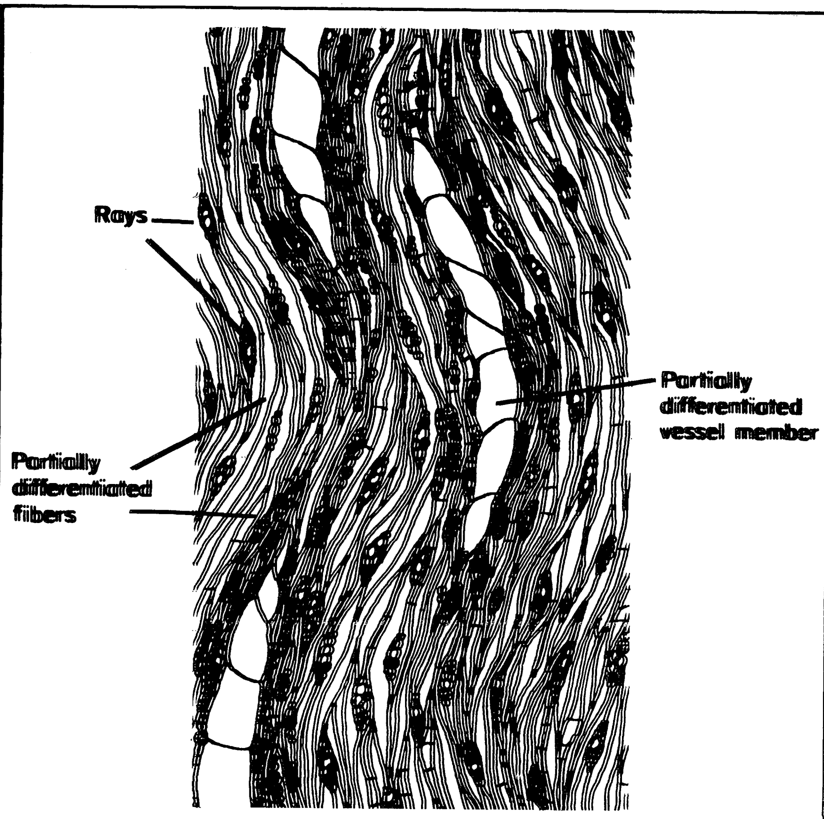


Figure 38. Section illustrating tangential displacement initiated by intrusive growth and elongation into restricted space.

figure in sugar maple contains indications of pathogenic activity involved in formation of this figure (11).

The common dimple figure in lodgepole pine (*Pinus contorta*) and several other coniferous species apparently has been traced to localized resin blisters in phloem (4, 17).

Drapē figure in mahogany, after many years of speculation concerning cause, finally was shown to be a result of complex actions of the strangler figure (39). The specific role of disease organisms in figure initiation is considered later.

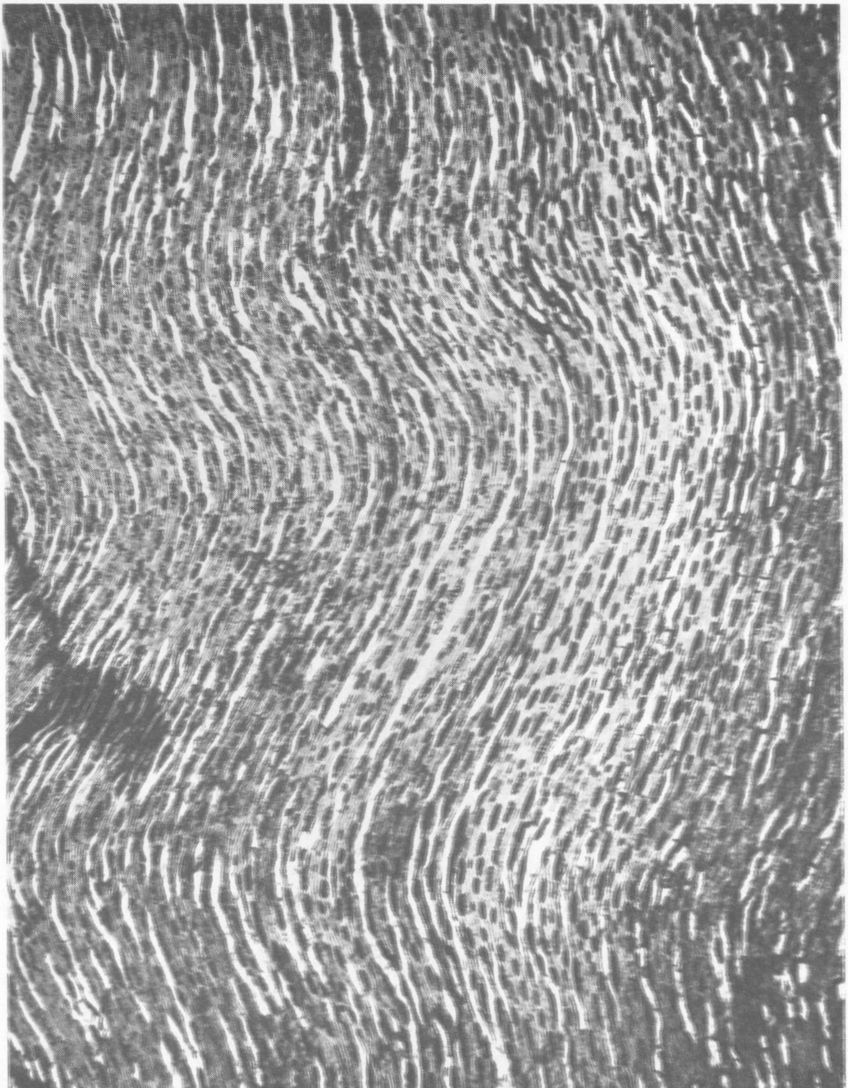


Figure 39. Photomicrograph that illustrates undulating growth in a tangential surface initiated by the process shown in figures 34 through 38.

Abnormal Tissues Associated with Figure

As a general rule, abnormal tissues such as compression wood and tension wood are not associated with figure types that affect the radial plane. It often has been observed, however, that types of figure that occur near branches or tree bases and on undersides of leaning trees may be accompanied by reaction wood. In well-formed figured wood where the pattern is regular, little reaction wood normally is encountered.

Tension wood often is associated with figure types that affect the tangential plane. In some cases, the entire blister surface is composed of tension wood. Export logs possessing blister or quilted figures, therefore, often require bands to reduce splits and checks. Loggers have reported that blister-figured logs sometimes seem to explode when cut (7). Enormous stresses may develop on the underside of leaning trees, where this figure characteristically is found. Tension wood adversely affects the finishing qualities of blister-figured wood but greatly enhances its luster.

External Expression

The most easily recognized external expression of figure in trees is an overgrowth commonly referred to as a burl. Burls are relatively large, abnormal bulges that sometimes form on trunks and limbs of almost any tree species (Figure 40). Burl surfaces may be corrugated or smooth, but usually are somewhat gnarled. Conifer burls generally are corrugated. Fiber alignment within burls, which is extremely irregular, produces a striking figure that is highly prized for veneer and turned articles. Burls for commercial use are obtained from Oregon myrtle *(Umbellularia californica),* elm, maple, walnut, and redwood *(Sequoia sempervirens).*

Dormant buds are frequently associated with burls (15, 24) and some burls apparently originate from single, well-defined points or series of points. Small burls develop outward, forming fan-shaped tissue masses, until several coalesce to fashion the typical burl figure (Figure 41).

Figures other than burl types rarely give external expressions that can be interpreted reliably as to quantity or quality of figure within the tree. Bark characteristics, while indicative of figure in birch, are not reliable guides (51, 55, 58). European birch with extremely rough bark is likely to have disturbed grain; smooth bark usually indicates straight grain (56).

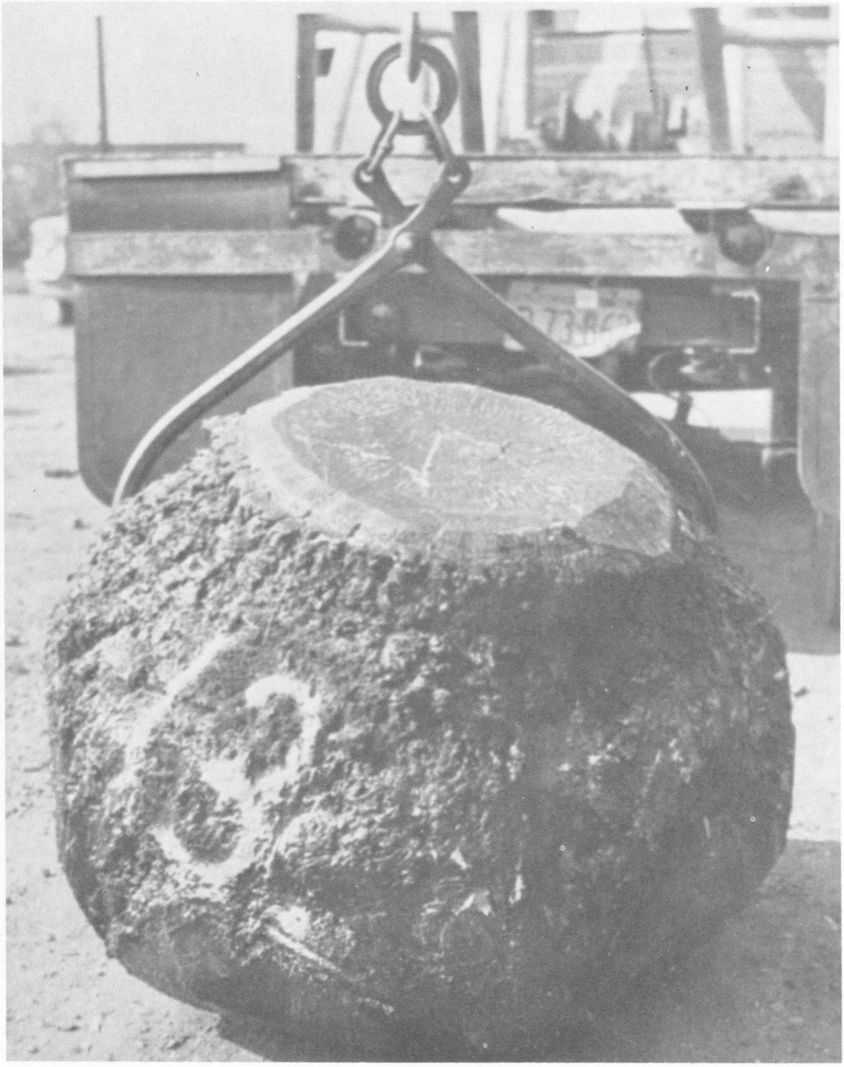


Figure 40. Walnut burl harvested and trimmed for export. (Photo: N. H. Beer & Associates)

Internal Expression

Figure that exists in rough logs often cannot be detected by visual inspection. Factors that indicate possible existence of figure are not normally visible until the log is debarked (figures 42 and 43). Even when presence of figure is indicated, quality and quantity often cannot be appraised.

Probably the surest method of checking extent and quality of figure is splitting a small section of the wood along the radial or tangential plane where the appropriate figure is exposed to best advantage (figures 44 and 45). There is no other method of determining interlocked grain, which is of periodic origin. The same test is useful in separating imper-

Figure 41. Transverse section through a burl from Oregon maple that illustrates many points of burl initiation (pointers) at various stem depths. Note fan-shaped outward development and coalescense of burl tissues.

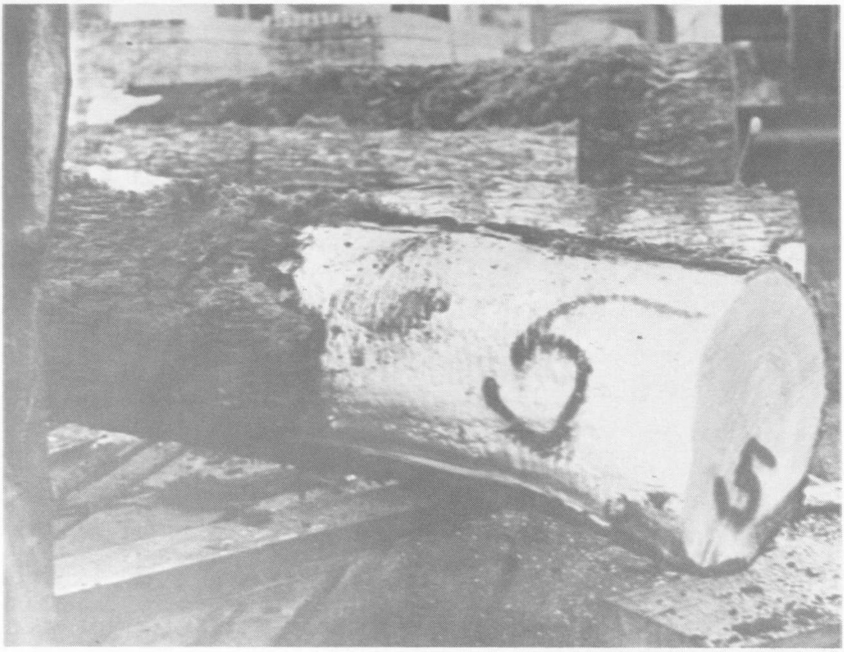


Figure 42. Partially debarked Oregon maple log that exhibits quilted figure. (Photo: N. H. Beer & Associates)

fectly formed figure types (some commonly called ghost figures) from well developed figure.

Split blocks that expose figure also illustrate how grain distortion forms the figures that are exhibited in veneer or lumber (Figure 46). Figure that is formed by gradual change in grain direction may not be readily apparent. Sawn surfaces frequently conceal any figure that might be present, or saw marks may give a false impression of figure when none is present. The split-block method is useful to ensure that figure is present and to indicate the cutting surfaces that will yield the most beautiful and interesting figure patterns (figures 47 and 48).

All four stem quadrants are generally sampled near the tree base to determine extent and penetration of figure and its quality. Additional samples are removed from various bole heights to determine longitudinal extent.

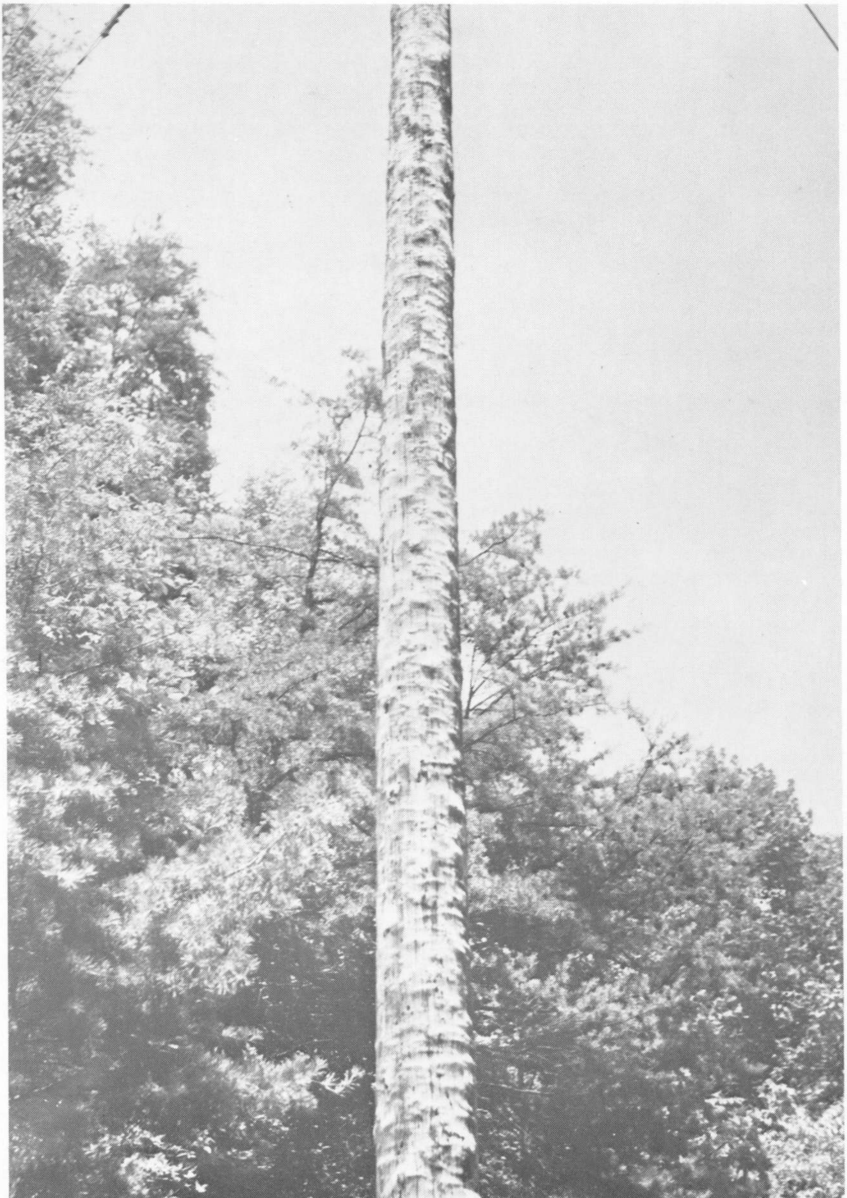


Figure 43. Utility pole of southern yellow pine with strong indications of blistér figure. Depth of figure cannot be determined without sampling.

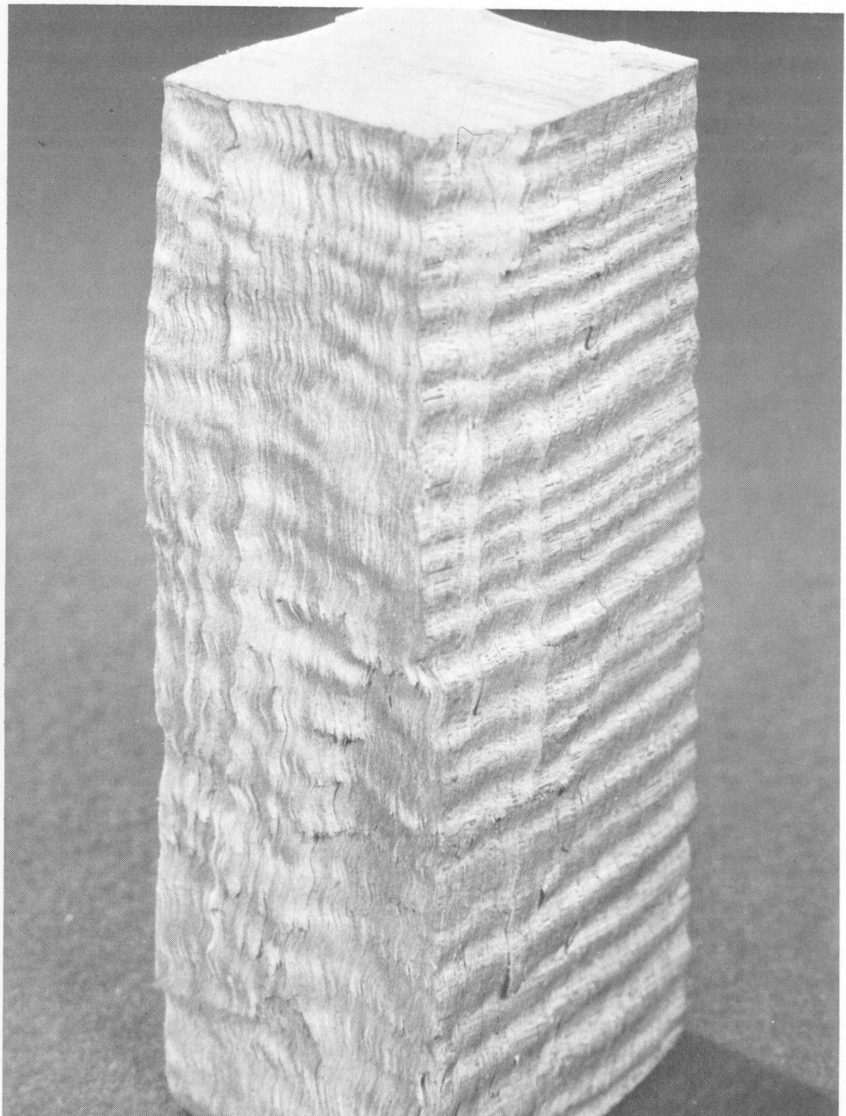


Figure 44. Split block of Oregon maple that shows well-developed fiddleback figure on the radial face (RIGHT) as indicated by corrugations.

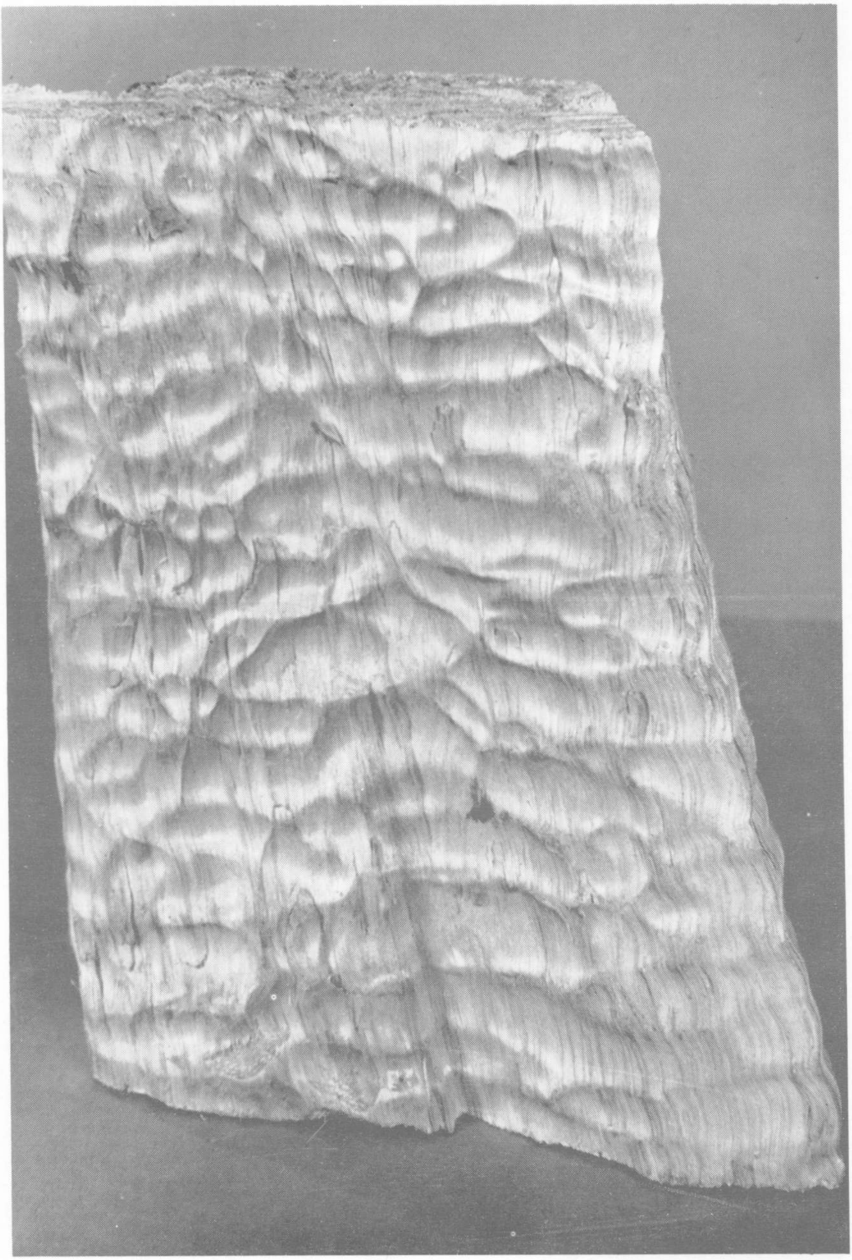


Figure 45. Split block of Oregon maple that exhibits high quality quilted figure on the tangential surface. (Material: N. H. Beer & Associates)

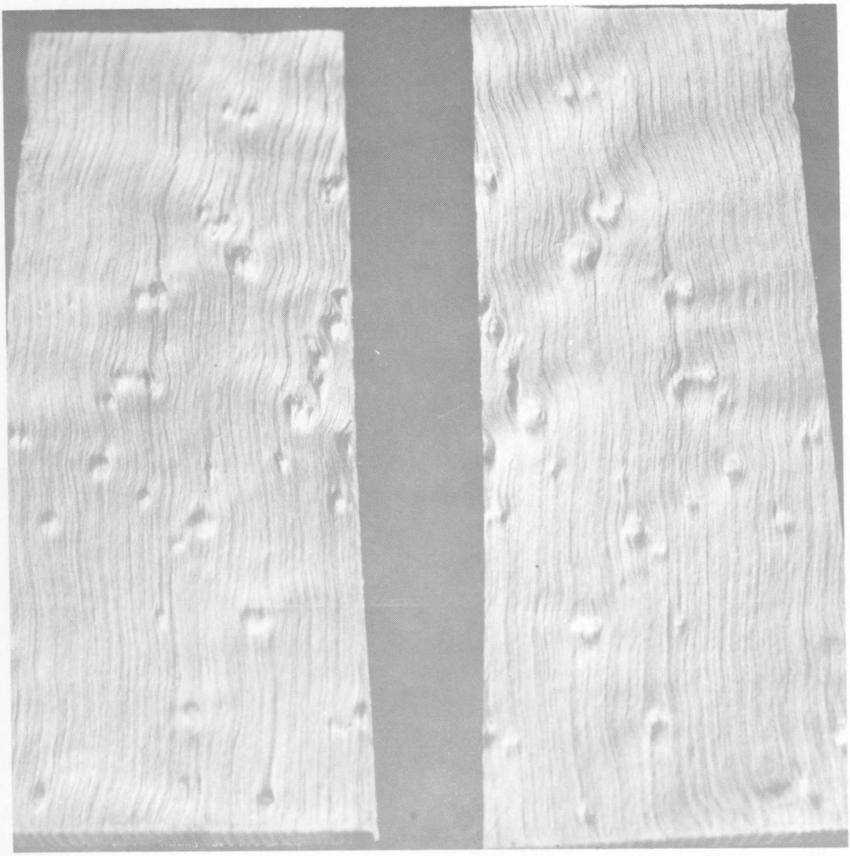


Figure 46. Split block of sugar maple that shows matching tangential surfaces of birdseye figure (depressions on left, bulges on right).

Figure 47. Large block of Claro walnut sawn through the pith, which illustrates figure development (r).

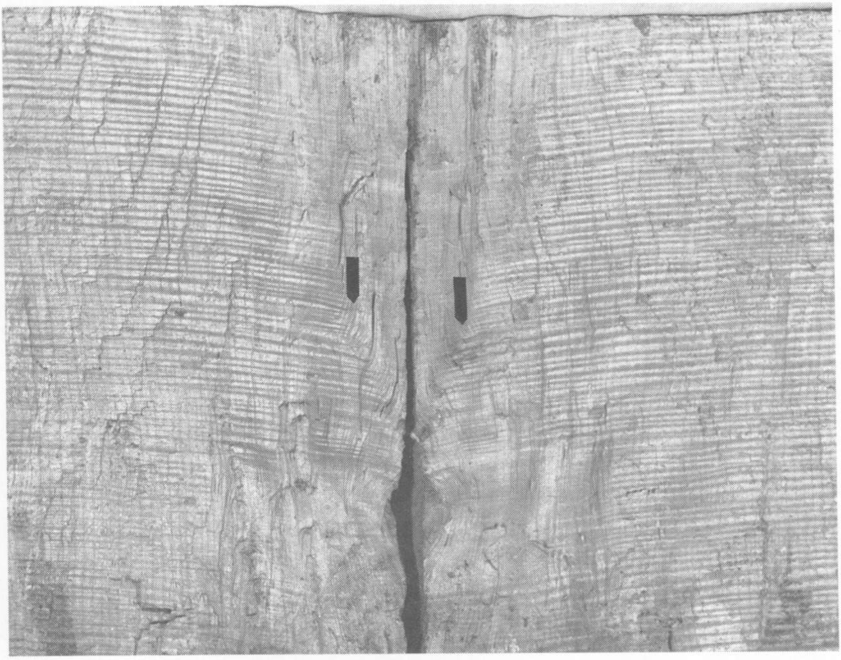


Figure 48. Large split block of Oregon maple that exhibits matching radial surfaces of high-quality fiddleback figure. Note abrupt figure development (pointer).

OPTICAL ILLUSIONS IN FIGURE

Optical illusions play an important part in formation of figure in wood (43). The fine, parallel, wavy lines produced in cutting tubular wood elements form the basis for a typical optical illusion (figures 16, 19, and 28).

Figure caused by undulating grain in wood is similar to striations formed in certain gemstones (particularly tigereye quartz and cats-eye) and various star figures found in sapphire, ruby, and quartz. Figure in these minerals is characterized by a moving light either in the form of a broad or narrow band or in the form of a "star." This phenomenon in gemstones is called "chatoyancy," referring to the eye of a cat. It is formed by the presence of tiny, parallel or divergent, tubular inclusions within gem crystals. When gemstones are cut *en cabonchon (i.e.* with a rounded top) a band of light appears to move as the stone is tilted. The figure is best observed, as in wood, when viewed with unilateral lighting or in sunlight.

Tigereye quartz exhibits figure most similar to that in wood because it is a pseudomorph of a wavy form of chrysotile (asbestos), a fibrous mineral. The undulating fibrous structure is reformed in chalcedony (quartz), where it becomes translucent. When fibers are cut at or near the peaks or valleys of undulations, differential refraction and absorption of light produce apparently moving, alternating bands. This produces stripes that change in color and intensity as the position of viewing is shifted from one side to the other and are similar to fiddleback figure of wood.

Figure also is a result, in part, of an interference pattern produced by light rays striking the fine, undulating fibrous elements contained within figured wood. This effect, as previously mentioned, can be observed in many materials of fibrous origin (including certain types of fabrics as well as in some minerals and gemstones). The effect often is produced deliberately in many man-made materials and in "op art" illusions by varying the distance between parallel lines or by varying the depth of striae. Figures in wood caused by wavy grain are enhanced by an optical interference effect (figure 49). The interference pattern takes the form of a narrow band that appears brighter than surrounding tissues and appears to move as the specimen or light direction is changed. This is caused partly by the "contrast-brightness" effect observed in many optical illusions of similar origin. The contrast-brightness effect is prominent in well-developed fiddleback, where it forms the bright band characteristic of this figure, and in birdseye figure, where it forms the "pupil" of the eye (Figure 33).

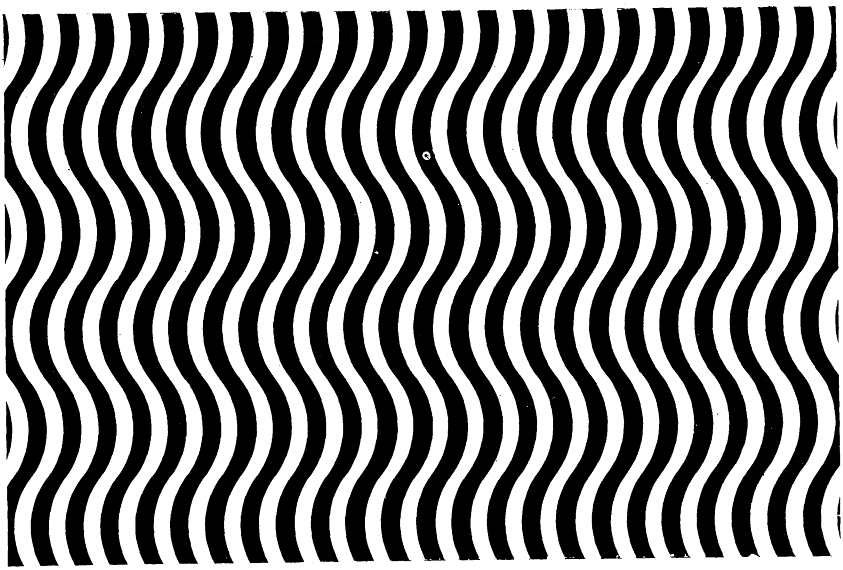


Figure 49. Optical illusion produced by equally-spaced parallel undulating lines. This is identical to optical illusions produced by fiddleback figure in wood.

These bands are augmented by light rays striking essentially parallel elements at peaks and valleys of the undulating grain. Elements at peaks are convex while those located in valleys are concave. As direction of viewing is changed or the position of the light angle is shifted laterally, the bright band also is shifted vertically. Some light rays become partially absorbed in the cut end-grain of steeply sloping elements and are partially refracted and reflected along the shallow walls of the more or less tubular elements that are exposed along their longitudinal axes.

In fabrics, related figures classified as moiré (watered) are formed by means of parallel lines producing wavy patterns of interference. Moiré patterns also are characterized by moving bands of light, although less prominent than those in gemstones. Similar figures also can be observed in cut-pile fabrics such as velvet or velour; they also occur in suede leather. All of these are similar to some of the figures that appear in wood.

EFFECT OF VARIOUS INFLUENCES ON FIGURE

Effect of Species

Figured wood occurs in almost every species that produces wood of commercial importance and in many non-commercial species. Most current information concerning figure in wood has been derived from species that supply the majority of figured woods of commerce.

In certain species (and possible varieties), individual figure types appear to be characteristic. For example, birdseye figure appears to be characteristic of sugar maple but also occurs in various specimens of ash, birch, and Cuban mahogany. Similar, but not identical, figure occurs in several softwood species.

Since figured trees occur sporadically in all species to a greater or lesser extent (72), it appears safe to conclude that species is not the deciding factor in figure formation.

Effect of Climate, Soils, and Location

No particular climate, soil, or geographical location appears to be essential to formation of figure in trees. Certain climates, soils, and geographical locations, however, can be cited as being conducive to formation of certain figure types in some species. For example, figured wood of several species currently is produced in the Pacific Northwest to a far greater extent than in other areas. One explanation for this fact may be that exploitation of hardwood species is relatively recent in the Pacific Northwest.

While it is true that several types of figure often are found in diseased or deformed trees, most of the best figured wood develops in well-formed, straight, healthy trees. Open-grown trees with short boles and wide branching appear to be influenced by factors conducive to figure formation. Considerable numbers of figured logs are harvested from grafted trees grown in orchards, particularly several varieties of English walnut propagated on various rootstocks (figures 50 and 51).

Certain areas appear to produce more figured trees than other areas. For example, birdseye figured sugar maple is common in northern portions of the natural range of this species but rarely occurs elsewhere. Curly figures are common in yellow birch in the northern U.S. and Canada and also in various species of birch in Europe. Fiddleback

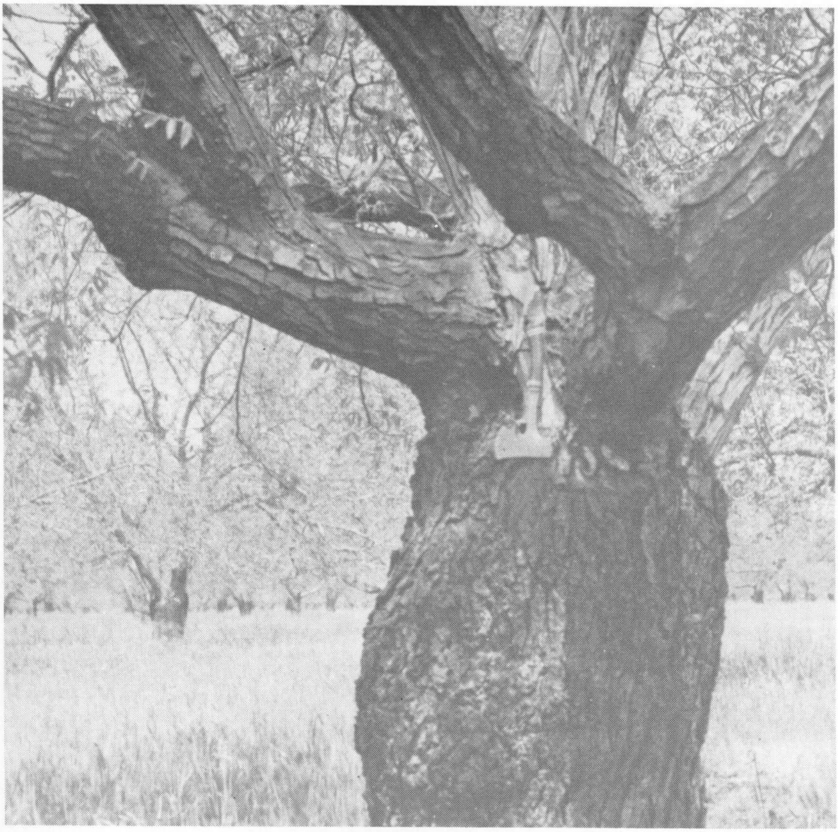


Figure 50. Grafted English walnut in a mature orchard (Claro walnut rootstock) that has passed the production stage. Such trees frequently produce figured wood in the understock. (Photo: N. H. Beer & Associates)

figure occurs commonly in sycamore maple in certain parts of Europe and in bigleaf maple in Oregon and Washington. Fiddleback occurs, but is less common, in sugar maple and various varieties of walnut grown on the West Coast. In contrast, interlocked grain woods are relatively rare in the U.S. but are so common in other areas of the world that this grain type is considered to be normal.

All figured wood types occur in almost every part of the world where figure is recognized. Based upon present knowledge, figure does not appear to be unique to any soil type, climate, hemisphere, or any other common factor. All types of figure occur in almost every species. Figure exists in only a few species to a commercially important extent.

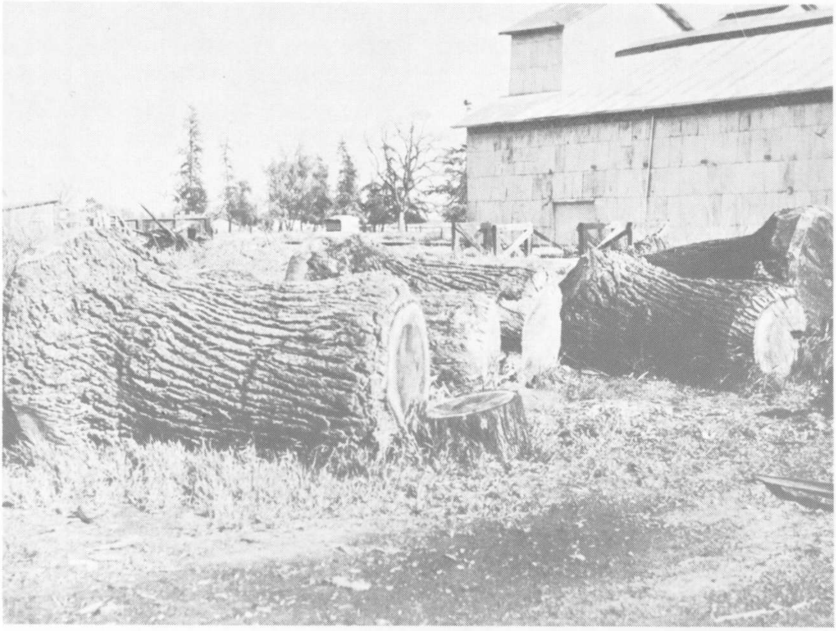


Figure 51. Export logs from a grafted English walnut orchard awaiting shipment. (Photo: N. H. Beer & Associates)

Effect of Growth Rate

Rate of growth apparently has some effect on the type or strength of figure produced. It often has been stated that growth retardation is a definite factor in figure formation and that the best development occurs only in slowly grown trees. Equal strength of figure, however, has been observed in rapidly grown specimens as in those grown slowly. Fast-grown wood is considered undesirable for certain products, which may prejudice the selection of figure in fast-grown wood.

The only figure type that has been studied in detail with regard to growth rate is birdseye figure in maple. During the early 1930's, it was concluded that growth rate is probably a minor factor (34, 35, 69).

Effect of Tree Size

Tree size apparently has little effect on figure; small and large trees have been observed to exhibit equally well developed curly and blister figures. However, there is some effect of tree size on the strength of figure because figure normally increases in intensity toward the bark.

This results in the best developed figure occurring in the outer areas of tree stems. There is usually a sterile, juvenile zone surrounding the pith that is devoid of figure and frequently contains reaction wood.

Commercial figured wood rarely occurs in trees less than 10 inches in diameter. Many small trees that may contain figure are overlooked because of size restrictions for veneer logs. These restrictions reduce the meaning of available size and figure correlations since much recorded information concerning this aspect is based on export-import data (10).

Effect of Disease

Some tree disease organisms characteristically cause their hosts or host parts to grow abnormally. This abnormal growth can be expressed either as undergrowth (hypotrophy) or overgrowth (hypertrophy). Either type might result in abnormal woody tissues. However, there also could be specific situations where the abnormality could be expressed only as a misalignment of cells and/or tissues.

Hypotrophic reactions of trees or tree parts can result from either subnormal cell division (hypoplasia) or degeneration of cells. Various disease agencies, both biotic and abiotic, can cause hypotrophic reactions. Unfavorable weather conditions (temperature extremes, *etc.*), unfavorable soil conditions (extremes of nutrition, water, *etc.*), or pathogenic organisms (viruses, bacteria, fungi, *etc.*) frequently cause hypotrophic reactions within trees.

Hypertrophic reactions of trees or tree parts result from an abnormal increase in cell numbers (hyperplasia), an abnormal increase in cell size (true hypertrophy), or both. These reactions may be expressed visually on merchantable portions of trees by various malformations and excrescences described as tumors, galls, or burls. There is no great difference in definition of these three terms except that the term, "burl," usually connotes a prominent overgrowth that is relatively common and has a commercial value. Most hypertrophic reactions of trees apparently are caused by various injuries, pathogenic organisms (especially bacteria), insects, or specific growth disorders. A brief summary concerning various aspects of tree galls/burls (both non-infectious and infectious) has been published (15).

Little evidence exists to support the theory that specific commercial figures are caused by disease organisms, but the literature cites many speculations to this effect. Burl portions of drapē figure in mahogany are induced by actions of parasitic rootlets of the strangler fig; swirl portions are induced mechanically where bulges form around constrictions caused by horizontal strands of vine (39).

Birdseye of sugar maple (30) and masur[4] figure in birch (41) formerly were thought to be induced by disease organisms. Present information, however, rejects these speculations except that a burl on birch associated with mazur is possibly induced by *Taphrina betulinum* (70).

Stem pitting of apple (48) and quick decline of citrus (14) produce wood similar to mazur figure in birch (33). It is generally believed that these conditions of apple and citrus are virus-induced, but there is some evidence to the contrary (16).

Most burls are initiated from single points (Figure 41), which may or may not indicate pathogenic activity. Microscopic examination of sections from various commercial types of figured wood usually shows no evidence of recognized pathogenic activity. Perhaps future work with virus diseases of woody plants will give more insight to some additional specific figures that are caused by disease.

ARTIFICIAL PRODUCTION OF FIGURE

Since the supply of figured wood always has been limited and its occurrence appears to be mostly a matter of chance, it is desirable to reproduce figured trees by vegetative propagation or to induce figure in normally unfigured trees (52). Few successful attempts of figure production by artificial means have been recorded. Near Kyoto, Japan, however, considerable success has been achieved in producing a blister figure referred to as "shibo" (crinkle figure) that occurs in Japanese cedar *(Cryptomeria japonica)* (61, 62). Shibo apparently occurs with several variations in size and shape of crinkles. Figured trees sometimes are propagated from cuttings taken from trees with figure of high quality. Crinkles develop in wood by the time cuttings are about 10 years of age, when the presence of figure can be recognized externally from their deeply fissured bark and a characteristic secretion of resin from the fissures. Japanese cedar with natural figure usually grows in a poor, stony soil in association with "kumassa" *(Sasa alba-marginata),* a broad-leaved pygmy bamboo.

Artifically produced crinkles sometimes are made mechanically in unfigured trees (61). First a 10-foot section of bole is smoothed and wound spirally with an elastic cord. A number of small bamboo sticks inserted between cord and bole are then tied firmly into place (Figure 52). The elastic cord is removed after the sticks are secured. Crinkle figure becomes evident after 2 or 3 years, when ties and sticks are removed. Blisters attain a rounded appearance approximating natural figure after the removal. When the figure has reached a desired state, the

[4]Masur also is spelled mazur, mazer, maser, and "wisa" depending upon the specific language.

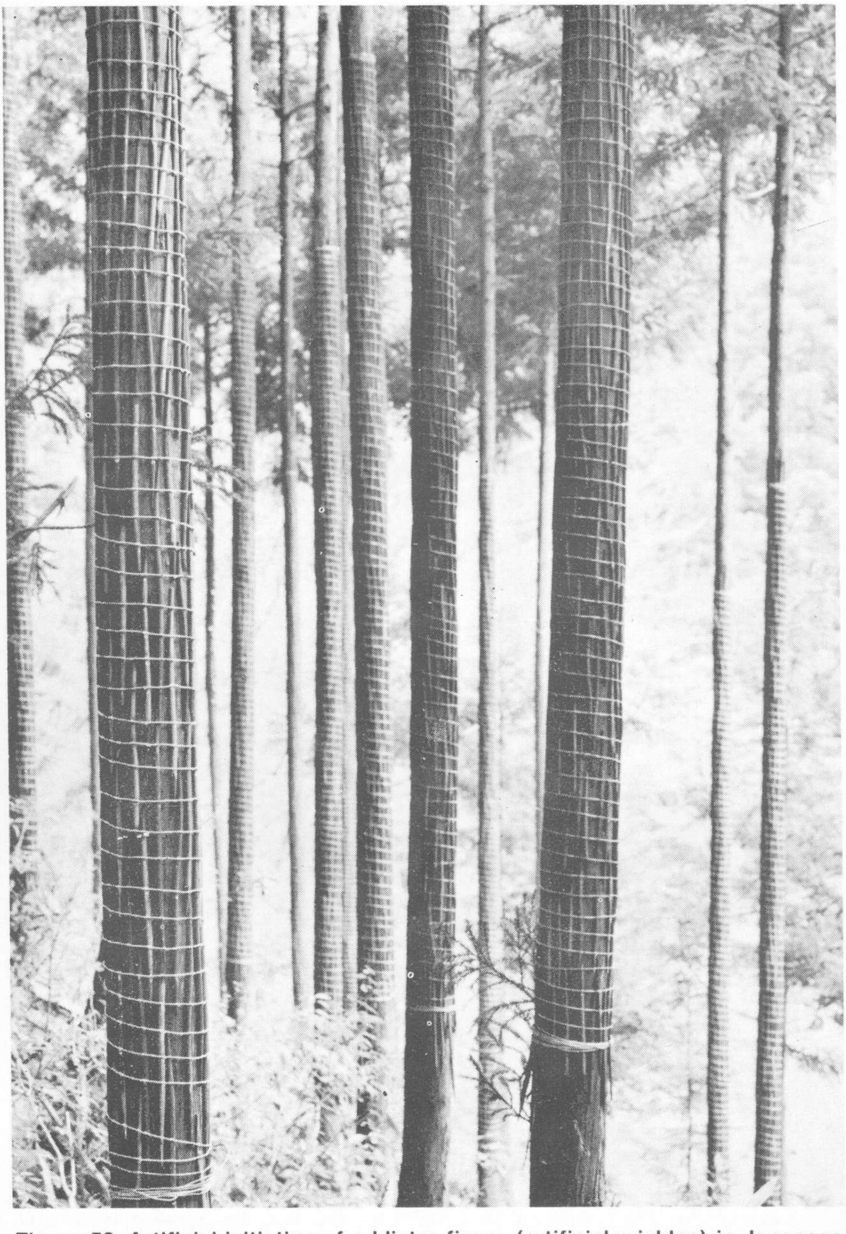


Figure 52. Artificial initiation of a blister figure (artificial crinkles) in Japanese Cedar. Note constricting bands and bamboo sticks that initiate bulges between ligatures (Photo A. Okazaki)

tree is cut, log sections are debarked, and figured surfaces are polished for use as alcove posts. Since the trees are not converted into lumber, this method apparently is practical only for products used in the round (62, 83). It was noted, however, that artificially produced figure often lacks the luster displayed by naturally figured trees.

Other attempts to induce figure mechanically are described in a detailed report made almost 30 years ago (5). Some of the trees described in this report still exist, but information concerning figure development is meager. These trees were examined several years following the mechanical treatment (along with some grafted trees) but no figured wood was detected; unusual bark characteristics were the only effect noted (79). The only natural mechanically produced figure of any value yet described is "drape" figure in mahogany, which is caused by complex actions of the strangler fig described previously (40).

It is unlikely that mechanical binding of stems or distortion will induce permanent figure in trees; even elastic ligatures are soon overgrown. While such constrictions create adjacent bulges, they rarely interrupt tissues sufficiently to cause definite figure (except as previously noted). It might be possible to induce blister-like figure in smooth-barked trees by means of reflective or absorbtive surfaces applied to tree trunks in desired patterns; this may cause differential growth of specific cambial areas. The two effects might be combined by applying patterns of black and reflective paints. Growth regulators applied in patterns might yield a similar result.

Success at reproducing figured trees by grafting has been inconsistent. Probably the most widely known grafted figured tree is the Lamb walnut, propagated in 1929 by J. F. Wilkinson of Rockport, Indiana (38). Specimens from grafted trees cut in 1951 showed figure in outer wood portions of 7- to 8-inch trees (81). Figure also was noted in branches of other grafted trees only 5 to 7 years of age (84). Aspects concerning growth of figured walnut trees were investigated (49). Several grafted plantings have been initiated in Europe (18, 19, 25).

Grafted specimens of birdseye-figured sugar maple apparently were planted in the early 1930's, but no records of any current living trees have been found (66). Grafted specimens of other figured trees have been produced but, again, records concerning their progress have not been published (42). Although European work with figured trees appears to exhibit more variation (73, 74, 75) intensive studies have been concentrated on "maser" figure in birch *(Betula verrucosa),* which is known to be quite variable (32, 36, 70, 71, 72). Several specimens of "maserbirch" have been reported in an arboretum near Poznań, Poland

(12) and in the Horsholm Arboretum in Denmark (41). A small European birch tree in plantings established by Bailey near Norris, Tennessee, was examined by the senior author in 1968. This tree exhibited indications of well-developed maser figure.

Burls commonly contain numerous apparently aborted buds that (as many persons believe) arose as a result of injury. Frost, fire, insect, and mechanical injuries are possible causes. Formation of burl-like growths in boxwood was induced by placing close-fitting metal bands around stems (65). Adventitious buds that formed near these bands produced swellings. A common practice in Algeria during the seventeenth and eighteenth centuries was inducing burl-like excrescences on African thuja by repeated burnings of stem portions (65), which consumed any sprouts that developed around injured areas. As a result, trunk swellings formed on sides opposite the burn injuries. Burl-like growths also develop in some cases through irritation of the cambium by viruses, bacteria, and fungi (as well as by a few higher plants). Repeated pollarding (limbs cut back to the trunk) occasionally will cause burl-like tissues to form.

GENETICS AND FIGURE

Little information is available concerning genetic effects on figure. Only eight of more than 150 Canadian and foreign workers in forest genetics contacted in 1968 were involved in some aspect of figure (13).

Summarization of research in Scandanavian genetic studies concerning maserbirch (37) resulted in seven conclusions:

(1) Maser figure varies in intensity and pattern;

(2) Maser characteristics are transferred by grafting;

(3) Maser characteristics can be transferred by seed;

(4) The maser property is dominant or semi-dominant;

(5) The homozygous condition is sublethal;

(6) Maser formation is caused by gene-controlled disturbances in the cambium area; and

(7) The maser condition is associated with slow growth and deformed trees.

No work in the U.S. has been directed toward genetic investigations of figure in recent years; little apparently is planned for the future. A genetic study in Puerto Rico (59) concerns transmission of giant birdseye figure in Cuban mahogany *(Sweitenia mahogani).*

An interesting aspect of fiddleback figure found in manaki mango from Hawaii is a condition of polyembryony never reported for any other mango species or variety (86). This tree is propagated primarily by vegetative means, but the figure apparently can be seed transmitted (86).

Efforts to reproduce curly or blister figures in walnut and birdseye figure in maple have not been consistently successful. A number of grafted stems now approaching 40 years of age have developed figure in some ramets but not in others (81).

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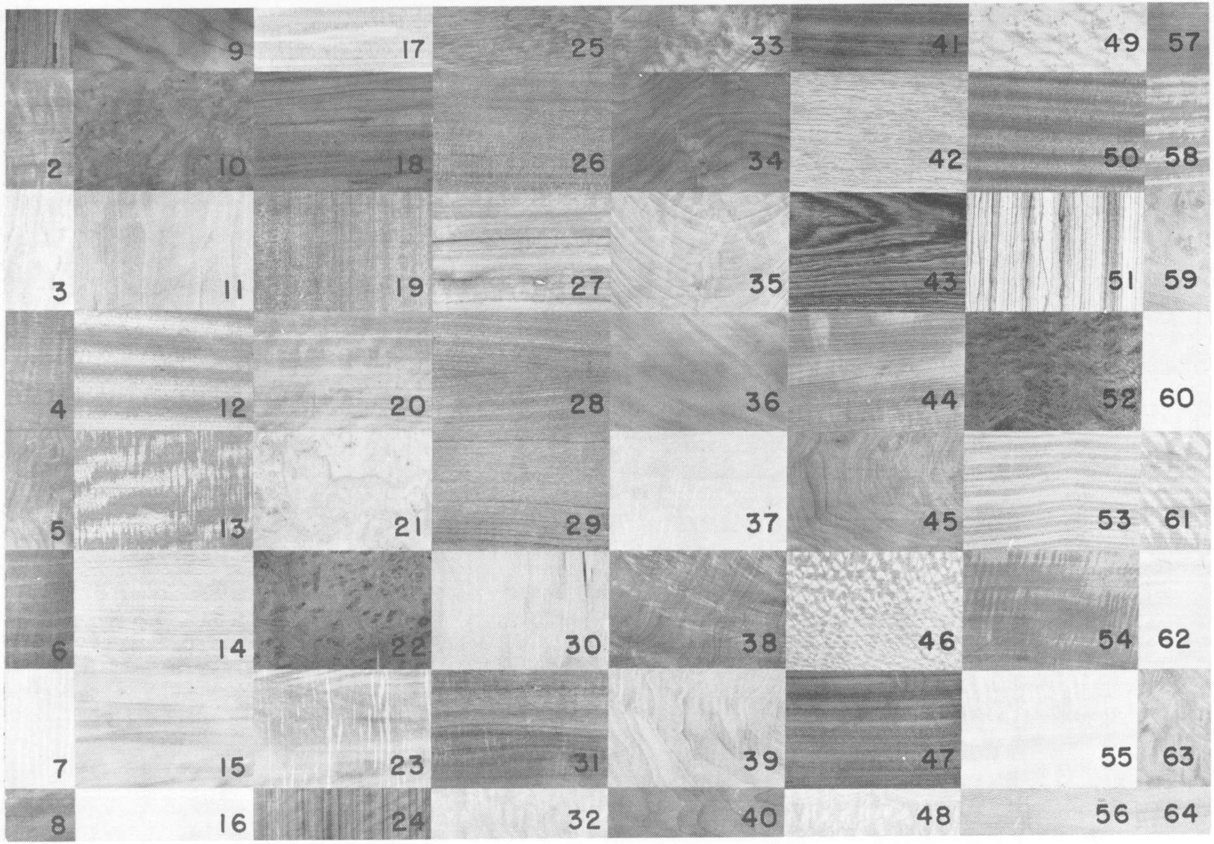
Faux-Rosewood MADAGASCAR 1	Claro Walnut Swirl U.S. 9	Prima Vera MEXICO 17	Quartered English Oak 25	Myrtle Burl U.S. 33	Kewasinga AFRICA 41	Birdseye Maple U.S. 49	Quartered Walnut U.S. 57
Figured Laurel INDIA 2	Madrone Burl U.S. 10	Quartered Claro Walnut U.S. 18	Plain Stripe Mahogany AFRICA 26	Moon Walnut U.S. 34	Rift White Oak U.S. 42	Sepeli AFRICA 50	Figured Satinwood INDIA 58
Maple Stump U.S. 3	Sap Walnut U.S. 11	Honduras Mahogany HONDURAS 19	New Guinea Wood NEW GUINEA 27	Faux Satine U.S. 35	Brazilian Rosewood BRAZIL 43	Zebrawood AFRICA 51	Carpathian Elm Burl EUROPE 59
Gray Harewood ENGLAND 4	Tigerwood AFRICA 12	French Walnut EUROPE 20	Burma Laurel INDIA 28	Swirl Mahogany AFRICA 36	Teakwood INDIA 44	Redwood Burl U.S. 52	Plain Capono MEXICO 60
Figured Walnut Crotch U.S. 5	Figured Striped Mahogany AFRICA 13	Maple Burl U.S 21	Plain Laurel INDIA 29	Figured Rotary Maple U.S. 37	Black Walnut Stump 45	Plain Satinwood INDIA 53	Figured New Guinea NEW GUINEA 61
Ebonized Maple U.S. 6	Butternut U.S. 14	Walnut Burl U.S. 22	Poplar U.S. 30	Mahogany Crotch AFRICA 38	Lacewood ASTRALIA 46	Figured Qtd. Claro Walnut U.S. 54	Figured Avodire AFRICA 62
Figured Quartered Maple U.S. 7	Figured Gum U.S. 15	Australian Maple Stump AUSTRALIA 23	Koa HAWAII 31	Sap Stump Walnut U.S. 39	Plain Orientalwood AUSTRALIA 47	Figured Capono MEXICO 55	Figured Rotary Walnut U.S. 63
Satinay AUSTRALIA 8	White Holly U.S. 16	Figured Orientalwood AUSTRALIA 24	Quilted Maple U.S. 32	Rotary Walnut U.S. 40	Tamo JAPAN 48	Sycamore U.S. 56	Bella Roas PHILIPPINE ISLANDS 64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